NIMBUS-B SOLAR-CONVERSION POWER SUPPLY SUBSYSTEM

QUARTERLY TECHNICAL REPORT NO. 6
DECEMBER 1966 THROUGH FEBRUARY 1967

Contract No. NAS5-9668

Prepared by

Astro-Electronics Division
Defense Electronic Products
Radio Corporation of America
Princeton, New Jersey

for

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland

NIMBUS-B SOLAR-CONVERSION POWER SUPPLY SUBSYSTEM

QUARTERLY TECHNICAL REPORT NO. 6
DECEMBER 1966 THROUGH FEBRUARY 1967

Contract No. NAS5-9668

Prepared by

Astro-Electronics Division
Defense Electronic Products
Radio Corporation of America
Princeton, New Jersey

for

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland

AED R-3164

Issued: April 14, 1967

PREFACE

This is the sixth in a series of quarterly technical reports on the development of the Solar-Conversion Power Supply Subsystem for the Nimbus-B Meteorological Satellite. This project is being conducted by the Astro-Electronics Division (AED) of RCA for the National Aeronautics and Space Administration (NASA) under Contract No. NAS5-9668. The present report covers the work accomplished during the period from December 1966 through February 1967.

PRECEDING PAGE BLANK NOT FILMED

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

SECTION I

SYSTEMS CONSIDERATIONS

A. INTRODUCTION

During the period of December 1, 1966 through February 28, 1967, the systems engineering effort consisted of:

(1) Preparation of documentation for the power subsystem performance specification and the subsystem instruction manual; and

(2) Updating of the Nimbus-B Energy Balance Computer Program.

B. DOCUMENTATION

1. Power Subsystem Performance Specification

This document was reviewed, corrected and approved. It was then released as RCA Drawing PS-1846666, "Performance Specification, Nimbus-B Solar-Conversion Power-Supply Subsystem."

2. Power Subsystem Instruction Manual

Copies of the power subsystem instruction manual have been submitted to GSFC for review.

C. COMPUTER PROGRAM

The Nimbus-B Energy Balance Computer Program has been revised and updated, on the basis of data obtained during engineering model system test, to provide the following items:

(1) Calculation and printout of the percentage depth of discharge (DOD) experienced by the batteries during a simulated orbit;

(2) Calculation and printout of the ampere-minute charge-discharge ratio achieved during a simulated orbit;

(3) Battery data tables describing the charge and discharge characteristics obtained during thermal-vacuum testing of the engineering model power subsystem; and

(4) System efficiency, based on the total power-subsystem losses measured during system testing and described in Quarterly Report No. 5. This system efficiency data will be used to refine any further calculations of the energy balance program.

SECTION II

CONTROL MODULE

A. GENERAL STATUS

1. Design

A new component board was designed to mount the filter components for suppressing the ripple spike voltage on the -24.5 volt regulated bus. This board is designated as A12, RCA 1965840-501. It is mounted in the connector compartment close to connectors J5, J6, J7 and J8. The original filter board, designated as A12, RCA 1768992-501 and located in the RFI compartment, was deleted from the assembly.

2. Engineering Model 2

Tests performed to suppress the ripple spikes on the -24.5 volt regulated bus were completed, and the new filter board, A12, was installed and tested. Fuses were changed to agree with the values specified by NASA, as listed in Quarterly Technical Report No. 5. The wiring harness was modified for testing of the prototype and flight component boards.

3. Prototype Module

Work on the prototype control module consisted of: (1) final assembly of the module, and (2) successful completion of electrical performance tests before and after potting.

4. Flight Modules

Final assembly of the first flight module was completed during this quarter.

B. BREADBOARD AND BENCH TESTS

1. Induced Failure Testing

The breadboard of the PWM regulator was subjected to induced component failures. The purpose of this testing was: (1) to verify or negate specific category 1 failure modes which had been postulated to exist in the Nimbus-B PWM regulator, and (2) to evaluate the performance of the regulator under these conditions.

The results of the failure-mode testing and the effect of these results on the reliability of the Nimbus-B power subsystem are given in Section VI of this report.

2. Suppression of Output Ripple Spikes

The ripple spike suppression filtering described in Quarterly Technical Report No. 5 was installed in its final form in engineering model 2. The output ripple spike was then measured at the output connector terminals (J5 through J8) under worst-case conditions (unregulated voltage of -38 volts and regulated bus current of 20 amperes).

The results of the test were documented in Report NB-SP-PO-117, and copies of the report were sent to NASA. A summary of the test results is given in Table 1. The values of output ripple obtained with the filtering were well within the value of 100 millivolts peak-to-peak specified in GSFC Specification S-652-P-1A.

TABLE 1. EFFECT OF RIPPLE SPIKE SUPPRESSION

Condition	Ripple (millivolts, peak-to-peak)	Normal Sawtooth Component (millivolts, peak-to-peak)	Spike Component (peak millivolts)
Without Filtering	160	80	80
With Filtering	90	80	10

3. Prototype Tests

Pre-potting and post-potting tests, over the temperature range of 0°C to +55°C, were performed in accordance with AED Test Procedure TP-BT-1759712. All measurements were within the specified limits, and all applicable requirements of the test procedure were met.

4. Telemetry Calibration

The telemetry outputs of the control module were calibrated. The telemetered parameters are unregulated bus voltage, regulated bus voltage, regulated bus current, solar array current, auxiliary regulator voltage, and main regulator 1 or 2 "ON." The calibration curves are shown in Figures 1 through 6.

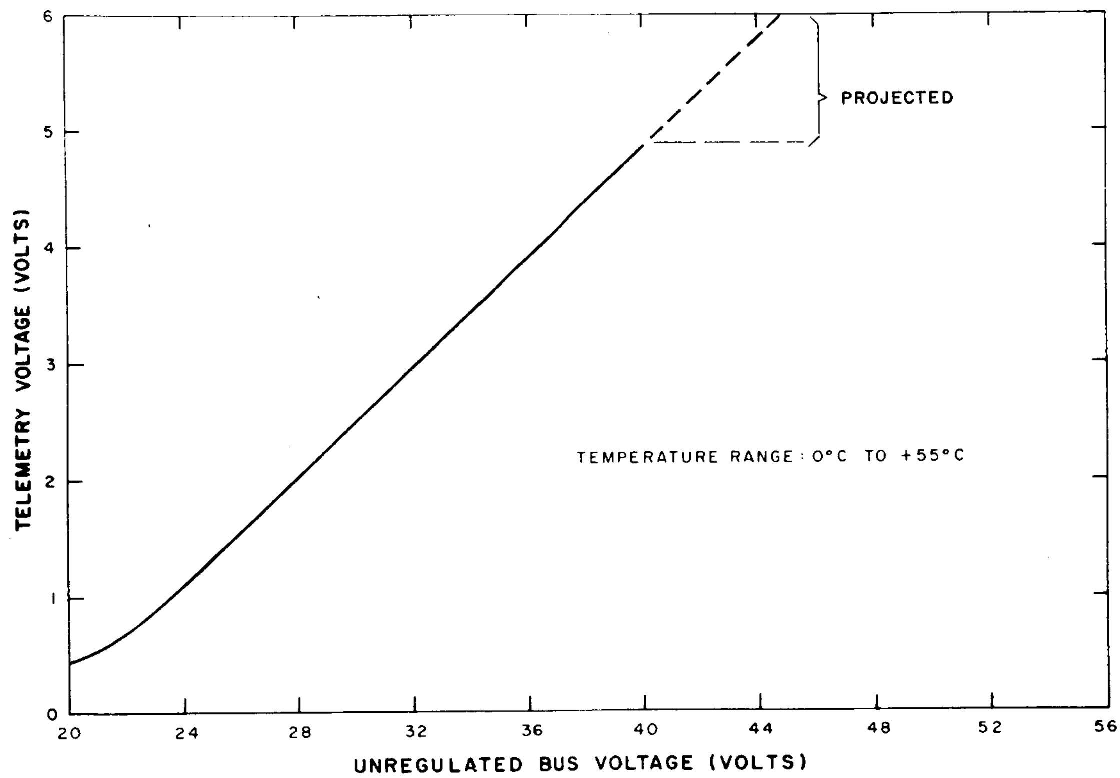


Figure 1. Telemetry Calibration Curve for Unregulated Bus Voltage, Control Module Serial No. 003

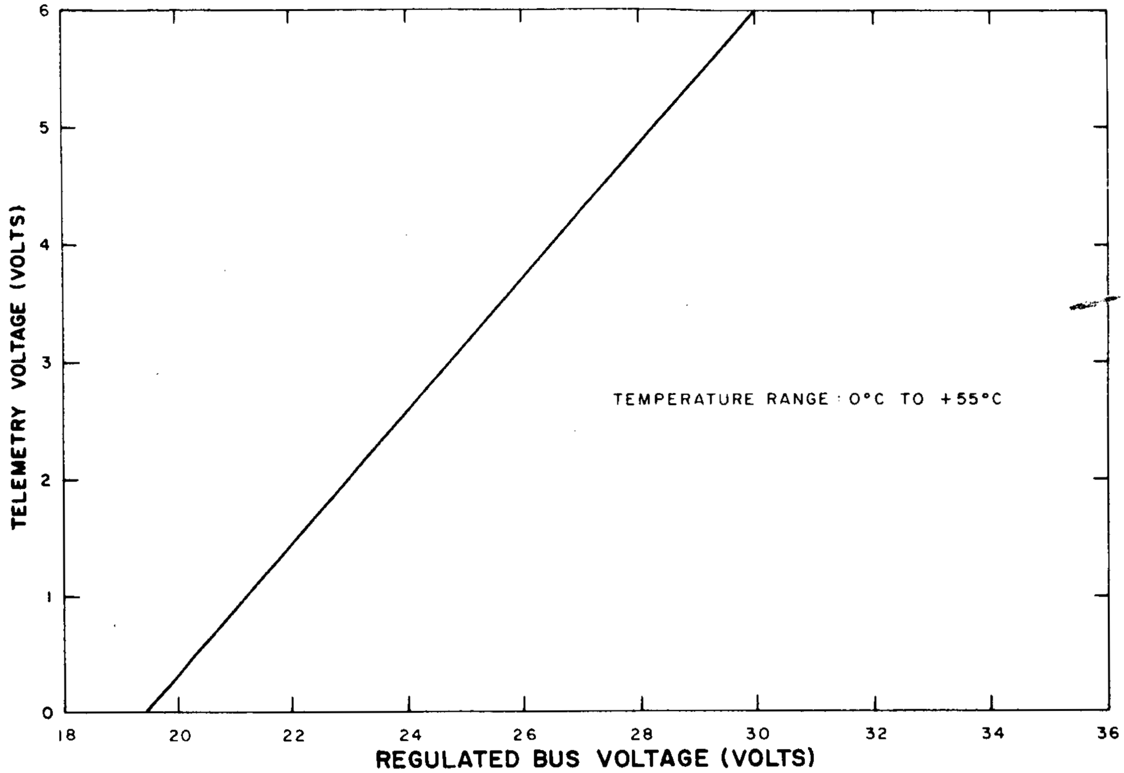


Figure 2. Telemetry Calibration Curve for Regulated Bus Voltage, Control Module Serial No. 003

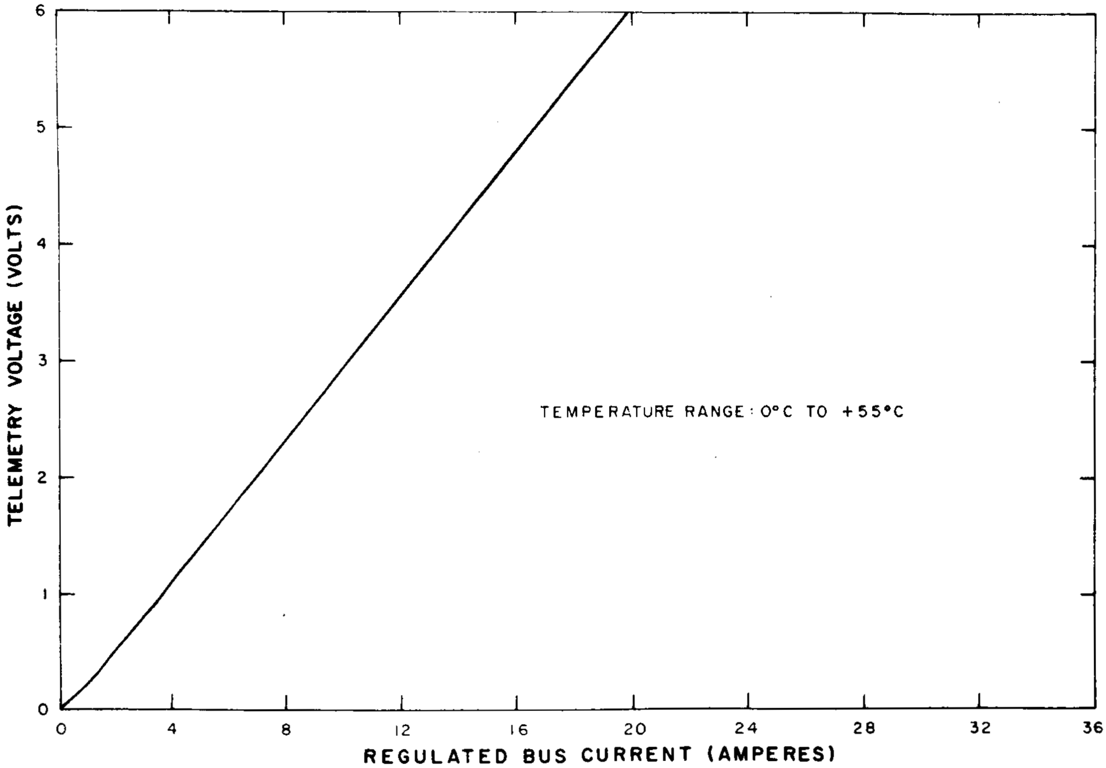


Figure 3. Telemetry Calibration Curve for Regulated Bus Current, Control Module Serial No. 003

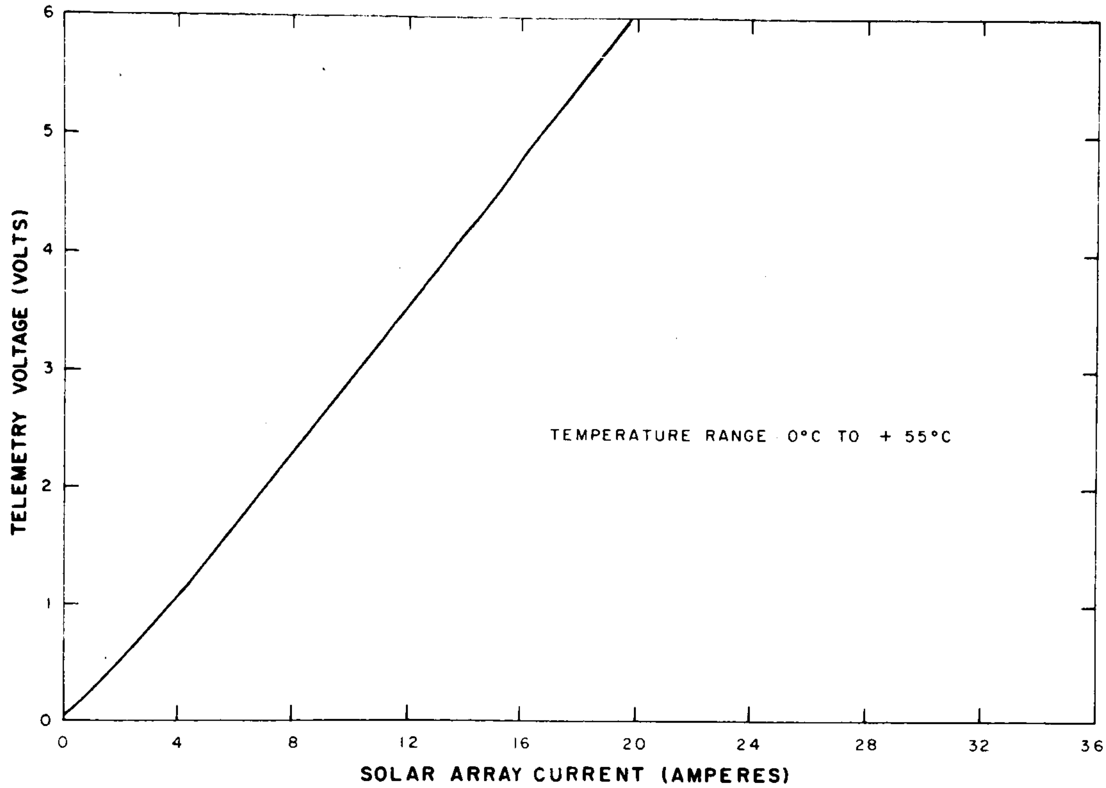


Figure 4. Telemetry Calibration Curve for Solar Array Current, Control Module Serial No. 003

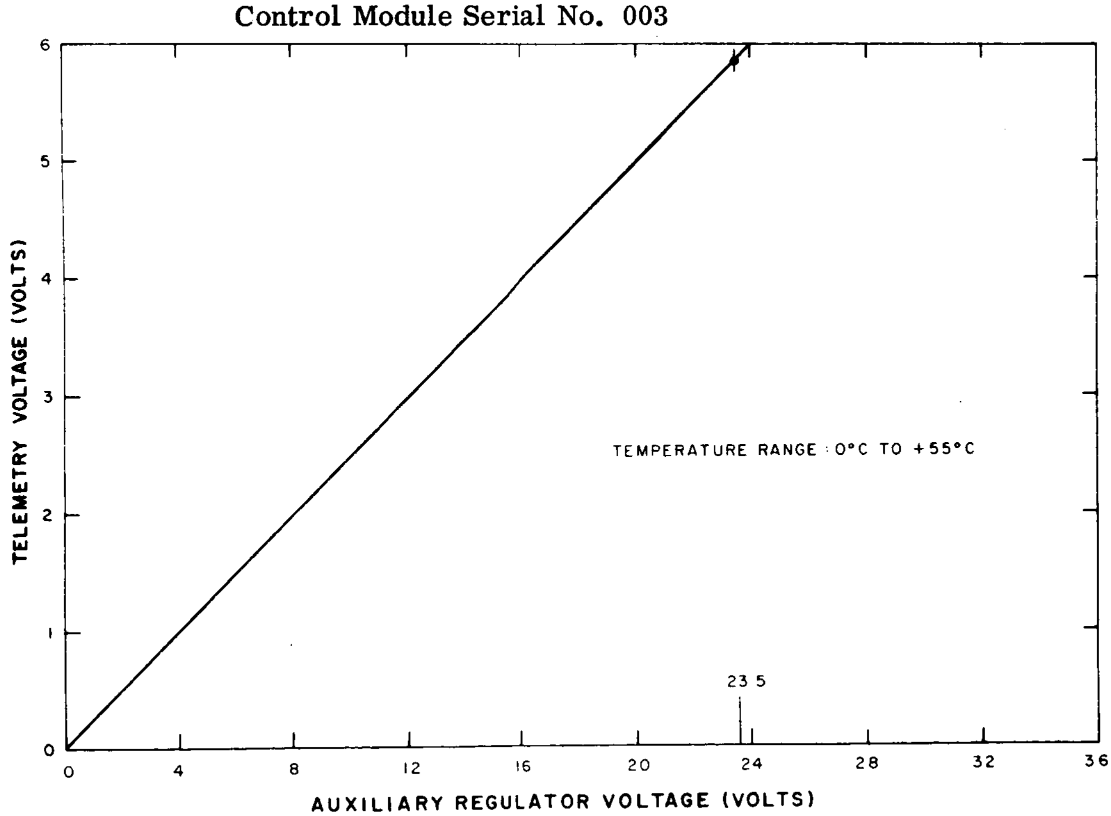


Figure 5. Telemetry Calibration Curve for Auxiliary Regulator Voltage, Control Module Serial No. 003

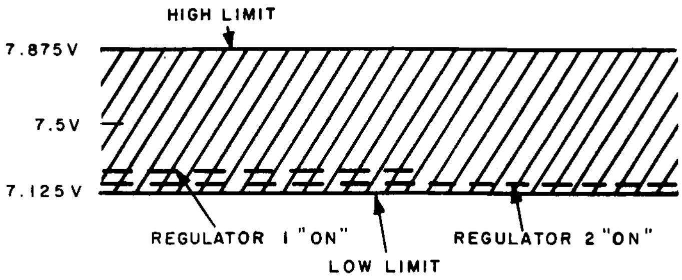


Figure 6. Telemetry Calibration Curve for Main Regulator 1 or 2 "ON", Control Module Serial No. 003

SECTION III

STORAGE MODULE

A. GENERAL

Work performed during this reporting period in connection with the storage modules consisted of the following:

(1) Acceptance testing of flight storage cells;

(2) Storage-cell cycling tests at various temperatures;

(3) Completion of final assembly of the two prototype modules;

(4) Electrical testing of the prototype modules; and

(5) Final assembly of the first three flight modules.

B. ACCEPTANCE TESTING OF FLIGHT STORAGE CELLS

1. General

A total of 344 cells were tested in accordance with the requirements of RCA Drawing 1750976, "Specification for Storage Cells (Nimbus B)", Revision C. The cells were manufactured by the General Electric Company of Gainesville, Florida.

2. Rejections

As a result of the acceptance testing, twenty-nine cells were found unacceptable for flight use. Five cells were rejected because of internal shorts, and 24 because of high charge voltage. The defective cells were returning to General Electric.

3. Summary of Test Results

Test data obtained during acceptance testing of the flight storage cells are summarized in Tables 2 through 12.

TABLE 2. SUMMARY OF TEST RESULTS, STORAGE MODULE SERIAL NO. 011

Module Position No.	Cell Serial No.	Average Capacity at 25°C (minutes)	Maximum Charging Voltage at 25°C (volts)	Cycling Test Maximum Voltage (volts)	Capacity at 50°C (minutes)	Capacity at 0°C (minutes)	Short Test Voltage at 20 Hours (volts)
1	21-19	159	1.475	1.488	91	134	1.202
2	21-23	159	1.442	1.483	93	132	1.202
3	21-25	160	1.437	1.481	91	133	1.200
4	21-29	159	1.421	1.466	91	134	1.208
5	24-18	160	1.426	1.462	90	134	1.199
6	21-43	160	1.449	1.481	91	133	1.203
7	21-55	159	1.450	1.481	96	132	1.199
8	22-1	160	1.424	1.479	99	131	1.203
9	22-2	159	1.420	1.480	100	131	1.204
10	22-5	160	1.426	1.482	99	132	1.206
11	22-20	160	1.417	1.459	98	133	1.202
12	22-28	160	1.417	1.465	100	131	1.200
13	22-40	160	1.421	1.476	98	133	1.201
14	22-43	160	1.421	1.469	100	133	1.203
15	22-45	160	1.426	1.480	99	133	1.203
16	23-4	159	1.442	1.476	98	126	1.215
17	23-5	159	1.433	1.469	97	130	1.218
18	23-7	159	1.447	1.479	96	131	1.218
19	21-36	159	1.429	1.475	99	132	1.200
20	24-42	159	1.442	1.474	87	141	1.210
21	26-9	159	1.443	1.475	90	133	1.196
22	26-31	159	1.436	1.497	91	134	1.199
23	29-20	159	1.431	1.494	99	132	1.203

Note: Capacity test discharges were performed at a 2.0-ampere rate.

TABLE 3. SUMMARY OF TEST RESULTS, STORAGE MODULE SERIAL NO. 012

Module Position No.	Cell Serial No.	Average Capacity at 25°C (minutes)	Maximum Charging Voltage at 25°C (volts)	Cycling Test Maximum Voltage (volts)	Capacity at 50°C (minutes)	Capacity at 0°C (minutes)	Short Test Voltage at 20 Hours (volts)
1	22-46	160	1.420	1.472	103	133	1.202
2	23-15	160	1.432	1.463	95	133	1.214
3	23-16	160	1.439	1.461	94	132	1.216
4	23-17	160	1.430	1.467	93	133	1.216
5	23-19	160	1.453	1.478	92	133	1.215
6	23-21	160	1.445	1.462	93	133	1.214
7	23-22	160	1.432	1.463	95	132	1.213
8	23-23	160	1.440	1.461	94	132	1.214
9	24-49	160	1.444	1.475	89	137	1.212
10	24-52	160	1.436	1.478	97	129	1.208
11	26-1	160	1.433	1.469	89	133	1.202
12	26-10	160	1.437	1.474	89	135	1.199
13	26-28	160	1.436	1.494	88	134	1.202
14	26-30	160	1.449	1.492	88	139	1.200
15	26-34	160	1.443	1.488	88	140	1.197
16	26-43	160	1.447	1.500	89	133	1.200
17	26-52	160	1.434	1.480	89	139	1.193
18	26-53	160	1.443	1.479	85	141	1.193
19	26-54	160	1.439	1.484	86	139	1.191
20	26-57	160	1.441	1.480	85	139	1.193
21	27-12	160	1.434	1.480	95	134	1.207
22	29-18	160	1.424	1.499	103	132	1.206
23	29-31	160	1.426	1.489	96	135	1.208

Note: Capacity test discharges were performed at a 2.0-ampere rate.

TABLE 4. SUMMARY OF TEST RESULTS, STORAGE MODULE SERIAL NO. 013

Module Position No.	Cell Serial No.	Average Capacity at 25°C (minutes)	Maximum Charging Voltage at 25°C (volts)	Cycling Test Maximum Voltage (volts)	Capacity at 50°C (minutes)	Capacity at 0°C (minutes)	Short Test Voltage at 20 Hours (volts)
1	19-54	161	1.432	1.456	83	133	1.212
2	19-59	161	1.425	1.455	91	133	1.212
3	19-61	161	1.429	1.468	91	132	1.213
4	19-62	161	1.438	1.483	92	133	1.212
5	21-4	161	1.437	1.491	91	133	1.206
6	21-30	161	1.437	1.478	90	135	1.204
7	21-32	161	1.426	1.459	91	134	1.204
8	21-49	161	1.436	1.484	93	134	1.208
9	21-50	161	1.427	1.477	97	131	1.204
10	21-52	161	1.438	1.484	95	133	1.204
11	21-54	161	1.432	1.485	97	134	1.201
12	22-6	161	1.424	1.470	98	133	1.204
13	22-15	161	1.420	1.467	97	133	1.204
14	22-18	161	1.422	1.466	96	133	1.205
15	22-19	161	1.423	1.471	97	134	1.206
16	22-29	161	1.419	1.459	99	134	1.201
17	22-30	161	1.418	1.459	98	133	1.199
18	22-38	161	1.422	1.473	97	133	1.200
19	23-13	161	1.448	1.476	93	133	1.216
20	23-18	161	1.445	1.472	93	135	1.216
21	23-33	161	1.433	1.468	94	133	1.210
22	24-1	161	1.420	1.467	100	131	1.204
23	24-2	161	1.431	1.471	98	133	1.201

Note: Capacity test discharges were performed at a 2.0-ampere rate.

TABLE 5. SUMMARY OF TEST RESULTS, STORAGE MODULE SERIAL NO. 014

Module Position No.	Cell Serial No.	Average Capacity at 25°C (minutes)	Maximum Charging Voltage at 25°C (volts)	Cycling Test Maximum Voltage (volts)	Capacity at 50°C (minutes)	Capacity at 0°C (minutes)	Short Test Voltage at 20 Hours (volts)
1	26-8	161	1.443	1.473	87	135	1.200
2	26-11	161	1.449	1.472	87	134	1.200
3	26-12	161	1.448	1.465	86	134	1.200
4	26-17	161	1.430	1.477	95	134	1.207
5	26-20	161	1.432	1.486	92	134	1.204
6	26-25	161	1.436	1.484	92	135	1.203
7	26-36	161	1.439	1.497	92	131	1.201
8	26-55	161	1.433	1.484	89	133	1.204
9	27-8	161	1.428	1.498	95	131	1.203
10	27-10	161	1.424	1.485	98	131	1.203
11	27-11	161	1.436	1.484	95	132	1.207
12	27-15	161	1.433	1.494	93	133	1.204
13	27-16	161	1.434	1.486	95	134	1.201
14	27-17	161	1.432	1.483	97	133	1.208
15	27-25	161	1.438	1.500	94	132	1.211
16	27-35	161	1.424	1.490	99	130	1.205
17	27-36	161	1.434	1.495	98	131	1.202
18	27-37	161	1.424	1.491	99	130	1.201
19	27-38	161	1.428	1.489	96	130	1.209
20	27-40	161	1.435	1.493	96	131	1.208
21	27-44	161	1.427	1.495	98	132	1.209
22	29-23	161	1.428	1.481	95	132	1.208
23	29-32	161	1.436	1.494	95	133	1.209

Note: Capacity test discharges were performed at a 2.0-ampere rate.

TABLE 6. SUMMARY OF TEST RESULTS, STORAGE MODULE SERIAL NO. 015

Module Position No.	Cell Serial No.	Average Capacity at 25°C (minutes)	Maximum Charging Voltage at 25°C (volts)	Cycling Test Maximum Voltage (volts)	Capacity at 50°C (minutes)	Capacity at 0°C (minutes)	Short Test Voltage at 20 Hours (volts)
1	21-1	162	1.439	1.488	94	134	1.208
2	21-18	162	1.425	1.474	94	135	1.206
3	21-34	162	1.428	1.461	90	137	1.203
4	21-37	162	1.427	1.465	91	136	1.205
5	21-38	162	1.427	1.456	90	136	1.204
6	21-40	162	1.426	1.458	92	136	1.202
7	21-41	162	1.433	1.474	90	136	1.205
8	21-46	162	1.424	1.467	93	137	1.205
9	21-48	162	1.425	1.462	94	136	1.203
10	22-8	162	1.421	1.466	99	132	1.205
11	22-33	162	1.425	1.467	98	134	1.199
12	26-14	162	1.433	1.483	91	135	1.202
13	26-21	162	1.430	1.482	91	136	1.202
14	26-23	162	1.430	1.484	96	134	1.204
15	26-63	162	1.434	1.488	87	135	1.204
16	27-2	162	1.434	1.487	94	133	1.206
17	27-4	162	1.432	1.481	93	132	1.204
18	27-5	162	1.429	1.489	95	132	1.209
19	27-30	162	1.435	1.498	96	133	1.210
20	27-45	162	1.433	1.495	95	134	1.210
21	27-58	162	1.430	1.488	96	134	1.202
22	27-60	162	1.434	1.489	96	133	1.204
23	29-25	162	1.427	1.478	93	134	1.201

Note: Capacity test discharges were performed at a 2.0-ampere rate.

TABLE 7. SUMMARY OF TEST RESULTS, STORAGE MODULE SERIAL NO. 016

Module Position No.	Cell Serial No.	Average Capacity at 25°C (minutes)	Maximum Charging Voltage at 25°C (volts)	Cycling Test Maximum Voltage (volts)	Capacity at 50°C (minutes)	Capacity at 0°C (minutes)	Short Test Voltage at 20 Hours (volts)
1	19-50	149	1.449	1.462	85	136	1.198
2	19-55	148	1.438	1.435	85	135	1.200
3	21-5	161	1.438	1.488	93	134	1.206
4	21-21	159	1.429	1.484	94	133	1.203
5	21-24	153	1.433	1.467	88	136	1.198
6	33-18	163	1.421	1.479	93	134	1.203
7	21-35	162	1.444	1.461	89	137	1.202
8	21-42	163	1.428	1.469	93	136	1.204
9	21-45	155	1.434	1.471	90	133	1.195
10	22-4	161	1.419	1.469	102	134	1.204
11	33-24	163	1.421	1.465	89	136	1.203
12	23-10	158	1.429	1.467	96	129	1.214
13	23-12	157	1.427	1.471	96	126	1.211
14	24-13	159	1.422	1.471	101	128	1.196
15	24-27	157	1.424	1.475	100	125	1.201
16	26-19	163	1.439	1.482	91	135	1.200
17	27-56	163	1.433	1.485	95	134	1.201
18	29-30	162	1.432	1.491	94	133	1.208
19	29-35	162	1.431	1.485	96	133	1.208
20	29-36	163	1.425	1.482	96	135	1.208
21	29-37	162	1.429	1.491	94	135	1.208
22	30-4	160	1.423	1.488	105	134	1.211
23	31-12	160	1.462	1.490	92	134	1.210

Note: Capacity test discharges were performed at a 2.0-ampere rate.

TABLE 8. SUMMARY OF TEST RESULTS, STORAGE MODULE SERIAL NO. 017

Module Position No.	Cell Serial No.	Average Capacity at 25°C (minutes)	Maximum Charging Voltage at 25°C (volts)	Cycling Test Maximum Voltage (volts)	Capacity at 50°C (minutes)	Capacity at 0°C (minutes)	Short Test Voltage at 20 Hours (volts)
1	27-29	162	1.428	1.455	87	132	1.203
2	27-47	162	1.424	1.460	92	133	1.200
3	27-53	162	1.424	1.485	96	138	1.206
4	27-61	162	1.433	1.471	92	132	1.207
5	29-3	162	1.421	1.477	93	123	1.206
6	29-34	162	1.423	1.475	95	139	1.207
7	30-3	162	1.429	1.483	102	134	1.210
8	30-7	162	1.421	1.480	101	139	1.203
9	30-10	162	1.419	1.493	101	138	1.204
10	31-2	162	1.444	1.489	97	134	1.211
11	31-17	162	1.442	1.488	91	135	1.212
12	31-21	162	1.445	1.486	93	133	1.211
13	31-24	162	1.430	1.477	91	132	1.210
14	31-41	162	1.427	1.463	89	132	1.211
15	31-65	162	1.431	1.477	91	132	1.211
16	32-18	162	1.441	1.472	87	132	1.208
17	32-28	162	1.440	1.480	91	133	1.207
18	33-5	162	1.423	1.471	89	134	1.205
19	33-6	162	1.423	1.468	89	134	1.205
20	33-10	162	1.427	1.472	91	134	1.204
21	33-12	162	1.422	1.478	92	134	1.205
22	33-15	162	1.420	1.476	93	132	1.204
23	33-19	162	1.421	1.469	90	134	1.204

Note: Capacity test discharges were performed at a 2.0-ampere rate.

TABLE 9. SUMMARY OF TEST RESULTS, STORAGE MODULE SERIAL NO. 018

Module Position No.	Cell Serial No.	Average Capacity at 25° C (minutes)	Maximum Charging Voltage at 25° C (volts)	Cycling Test Maximum Voltage (volts)	Capacity at 50° C (minutes)	Capacity at 0° C (minutes)	Short Test Voltage at 20 Hours (volts)
1	32-24	161	1.437	1.472	89	132	1.207
2	33-2	161	1.421	1.467	88	133	1.204
3	33-3	161	1.422	1.466	89	133	1.203
4	33-4	161	1.422	1.464	89	134	1.204
5	33-7	161	1.424	1.474	91	132	1.205
6	33-9	161	1.423	1.480	89	133	1.206
7	33-17	161	1.422	1.471	89	134	1.206
8	33-20	162	1.421	1.464	91	134	1.205
9	33-22	162	1.422	1.462	88	134	1.205
10	33-25	161	1.424	1.462	85	135	1.205
11	33-27	162	1.424	1.472	92	134	1.205
12	33-29	161	1.422	1.479	90	134	1.206
13	33-30	162	1.424	1.460	88	135	1.207
14	33-31	161	1.427	1.477	91	136	1.205
15	33-32	162	1.423	1.473	92	135	1.206
16	33-33	161	1.427	1.486	91	136	1.207
17	33-44	161	1.423	1.488	96	134	1.206
18	33-50	161	1.427	1.491	95	135	1.206
19	33-53	161	1.425	1.496	95	136	1.204
20	33-80	161	1.426	1.477	89	134	1.205
21	33-83	162	1.428	1.471	87	135	1.202
22	34-2	161	1.427	1.471	89	135	1.203
23	34-27	161	1.435	1.472	85	134	1.206

Note: Capacity test discharges were performed at a 2.0-ampere rate.

TABLE 10. SUMMARY OF TEST RESULTS, STORAGE MODULE SERIAL NO. 019

Module Position No.	Cell Serial No.	Average Capacity at 25° C (minutes)	Maximum Charging Voltage at 25° C (volts)	Cycling Test Maximum Voltage (volts)	Capacity at 50° C (minutes)	Capacity at 0° C (minutes)	Short Test Voltage at 20 Hours (volts)
1	24-25	161	1.418	1.498	101	136	1.203
2	25-38	161	1.436	1.448	76	137	1.207
3	25-50	161	1.425	1.462	82	136	1.215
4	26-2	161	1.431	1.472	88	134	1.199
5	26-35	161	1.447	1.478	89	131	1.201
6	26-41	161	1.476	1.477	87	134	1.205
7	26-61	160	1.436	1.478	87	141	1.193
8	27-39	161	1.441	1.465	91	133	1.196
9	27-55	161	1.423	1.486	90	132	1.208
10	29-17	160	1.431	1.478	95	130	1.206
11	29-22	161	1.425	1.479	98	136	1.200
12	29-39	161	1.431	1.490	94	134	1.208
13	29-40	161	1.421	1.477	95	139	1.206
14	29-42	161	1.430	1.481	97	134	1.210
15	30-14	161	1.439	1.493	103	132	1.210
16	31-3	161	1.445	1.497	94	133	1.212
17	31-5	161	1.429	1.486	94	138	1.210
18	31-9	160	1.462	1.485	92	132	1.208
19	31-13	161	1.446	1.476	94	133	1.212
20	31-30	161	1.430	1.491	97	133	1.210
21	31-35	161	1.429	1.461	89	133	1.208
22	31-57	161	1.444	1.486	93	132	1.209
23	32-27	160	1.466	1.476	90	130	1.205

Note: Capacity test discharges were performed at a 2.0-ampere rate.

TABLE 11. SUMMARY OF TEST RESULTS, STORAGE MODULE SERIAL NO. 020

Module Position No.	Cell Serial No.	Average Capacity at 25° C (minutes)	Maximum Charging Voltage at 25° C (volts)	Cycling Test Maximum Voltage (volts)	Capacity at 50° C (minutes)	Capacity at 0° C (minutes)	Short Test Voltage at 20 Hours (volts)
1	26-7	159	1.427	1.465	88	132	1.202
2	26-33	158	1.452	1.481	86	138	1.195
3	26-42	158	1.455	1.496	89	139	1.198
4	26-58	159	1.432	1.486	85	140	1.192
5	26-64	158	1.442	1.473	83	142	1.191
6	26-65	159	1.448	1.478	83	140	1.191
7	27-1	161	1.424	1.484	91	136	1.202
8	31-4	159	1.448	1.487	91	133	1.207
9	31-10	159	1.447	1.478	91	135	1.206
10	32-29	160	1.461	1.478	90	130	1.205
11	33-16	160	1.423	1.478	93	130	1.205
12	33-34	160	1.431	1.471	90	135	1.206
13	33-35	160	1.431	1.474	91	134	1.208
14	33-39	160	1.428	1.466	88	135	1.206
15	33-41	160	1.423	1.485	92	132	1.209
16	33-42	159	1.436	1.477	91	138	1.199
17	33-48	159	1.438	1.481	91	138	1.201
18	33-58	160	1.432	1.471	90	136	1.204
19	33-60	160	1.427	1.473	90	135	1.206
20	33-69	160	1.425	1.482	88	136	1.205
21	33-72	160	1.426	1.478	86	135	1.205
22	34-18	160	1.422	1.461	89	133	1.203
23	34-25	158	1.431	1.469	84	133	1.203

Note: Capacity test discharges were performed at a 2.0-ampere rate.

TABLE 12. SUMMARY OF TEST RESULTS, STORAGE MODULE SERIAL NO. 021

Module Position No.	Cell Serial No.	Average Capacity at 25° C (minutes)	Maximum Charging Voltage at 25° C (volts)	Cycling Test Maximum Voltage (volts)	Capacity at 50° C (minutes)	Capacity at 0° C (minutes)	Short Test Voltage at 20 Hours (volts)
1	21-17	162	1.418	1.464	92	134	1.208
2	21-53	162	1.425	1.474	93	134	1.206
3	27-50	162	1.426	1.459	91	133	1.199
4	31-15	159	1.435	1.487	91	126	1.206
5	31-39	162	1.431	1.467	91	130	1.217
6	31-44	164	1.432	1.479	91	132	1.206
7	31-45	163	1.436	1.482	92	132	1.207
8	31-49	163	1.434	1.466	88	134	1.211
9	31-50	163	1.436	1.468	89	133	1.210
10	31-51	162	1.453	1.478	90	130	1.206
11	31-52	163	1.433	1.469	90	134	1.210
12	31-56	162	1.431	1.476	91	129	1.213
13	31-59	162	1.433	1.484	95	131	1.210
14	31-60	160	1.432	1.488	95	127	1.214
15	31-62	161	1.440	1.483	92	131	1.212
16	32-2	162	1.440	1.469	86	133	1.207
17	32-9	163	1.445	1.464	85	136	1.206
18	32-11	163	1.433	1.466	85	134	1.206
19	32-15	163	1.439	1.466	85	133	1.207
20	32-16	161	1.457	1.473	85	133	1.208
21	32-17	161	1.437	1.473	84	132	1.209
22	32-22	161	1.443	1.477	88	132	1.209
23	32-40	164	1.426	1.476	90	135	1.206

Note: Capacity test discharges were performed at a 2.0-ampere rate.

TABLE 13. SUMMARY OF TEST RESULTS, SPARE-CELL MODULE SERIAL NO. 001

Module Position No.	Cell Serial No.	Average Capacity at 25° C (minutes)	Maximum Charging Voltage at 25° C (volts)	Cycling Test Maximum Voltage (volts)	Capacity at 50° C (minutes)	Capacity at 0° C (minutes)	Short Test Voltage at 20 Hours (volts)
1	27-21	162	1.435	1.455	91	134	1.203
2	26-6	162	1.429	1.465	88	134	1.202
3	26-40	162	1.435	1.498	97	130	1.200
4	27-3	162	1.431	1.480	91	137	1.204
5	27-6	162	1.433	1.466	87	132	1.206
6	27-7	162	1.426	1.463	90	134	1.198
7	27-9	162	1.429	1.455	88	132	1.203
8	27-14	163	1.431	1.459	90	135	1.196
9	27-18	162	1.432	1.457	90	134	1.195
10	27-49	163	1.429	1.465	91	134	1.198
11	31-11	163	1.437	1.488	95	131	1.209
12	31-42	163	1.429	1.467	90	133	1.208
13	31-46	164	1.429	1.461	90	135	1.207
14	31-55	163	1.435	1.466	87	135	1.209
15	31-67	163	1.432	1.472	93	133	1.206
16	31-70	163	1.426	1.483	92	138	1.208
17	32-1	163	1.439	1.471	84	134	1.207
18	32-5	163	1.435	1.465	94	135	1.206
19	32-13	163	1.434	1.465	88	134	1.205
20	32-32	163	1.434	1.468	84	133	1.205
21	32-38	163	1.424	1.484	96	135	1.205
22	32-41	164	1.424	1.473	89	135	1.205
23	32-42	164	1.427	1.478	89	135	1.205

Note: Capacity test discharges were performed at a 2.0-ampere rate.

C. STORAGE-CELL CYCLING TESTS AT VARIOUS TEMPERATURES

Four groups of 23 cells each, which had been used in the parametric study, were subjected to a simulated orbital cycling program. Voltage-limited charge control techniques of the Nimbus-B type were employed in the program. The four cell-groups were maintained at temperatures of 15, 25, 35 and 45°C, respectively. The temperature of each group was held constant.

Two test profiles were used. The first, designated Profile A, represents the nominal system with the RTG. The second, Profile B, represents the nominal system with an inoperative RTG. The two profiles are detailed in Table 14.

TABLE 14. SIMULATED ORBITAL-CYCLING TEST PROFILES

<table>
<tr><th rowspan="2" colspan="2">Orbital Time (minutes)</th><th colspan="4">Battery Current (amperes)</th></tr>
<tr><th colspan="2">Profile A</th><th colspan="2">Profile B</th></tr>
<tr><td colspan="2">0 to 35</td><td colspan="2">0.875 discharge</td><td colspan="2">1.12 discharge</td></tr>
<tr><td colspan="2">35 to 90</td><td colspan="2">0.90 maximum charge</td><td colspan="2">0.68 maximum charge</td></tr>
<tr><td colspan="2">90 to 98</td><td colspan="2">0.250 maximum charge</td><td colspan="2">zero</td></tr>
<tr><td colspan="2">98 to 108</td><td colspan="2">0.90 maximum charge</td><td colspan="2">0.68 maximum charge</td></tr>
<tr><td colspan="6">The battery charge voltages are limited as follows:</td></tr>
<tr><th>Temperature (°C)</th><th>Charge voltage (volts)</th><th colspan="2">Temperature (°C)</th><th colspan="2">Charge Voltage (volts)</th></tr>
<tr><td>15</td><td>34.10</td><td colspan="2">35</td><td colspan="2">33.08</td></tr>
<tr><td>25</td><td>33.58</td><td colspan="2">45</td><td colspan="2">32.67</td></tr>
</table>

Approximately 600 simulated orbits were run. Of this number, 280 were Profile A and the remainder were Profile B. End-of-discharge voltage versus orbit number is plotted in Figure 7. The discontinuity after the first 112 orbits of Profile B is due to a test shutdown. The test was temporarily discontinued at that time because the test equipment was needed for the Nimbus-B engineering model tests. During the shutdown period, the cells were fully discharged and, subsequently, were fully charged. The rise in the end-of-discharge voltages at the resumption of testing is due to this cell conditioning and full recharge.

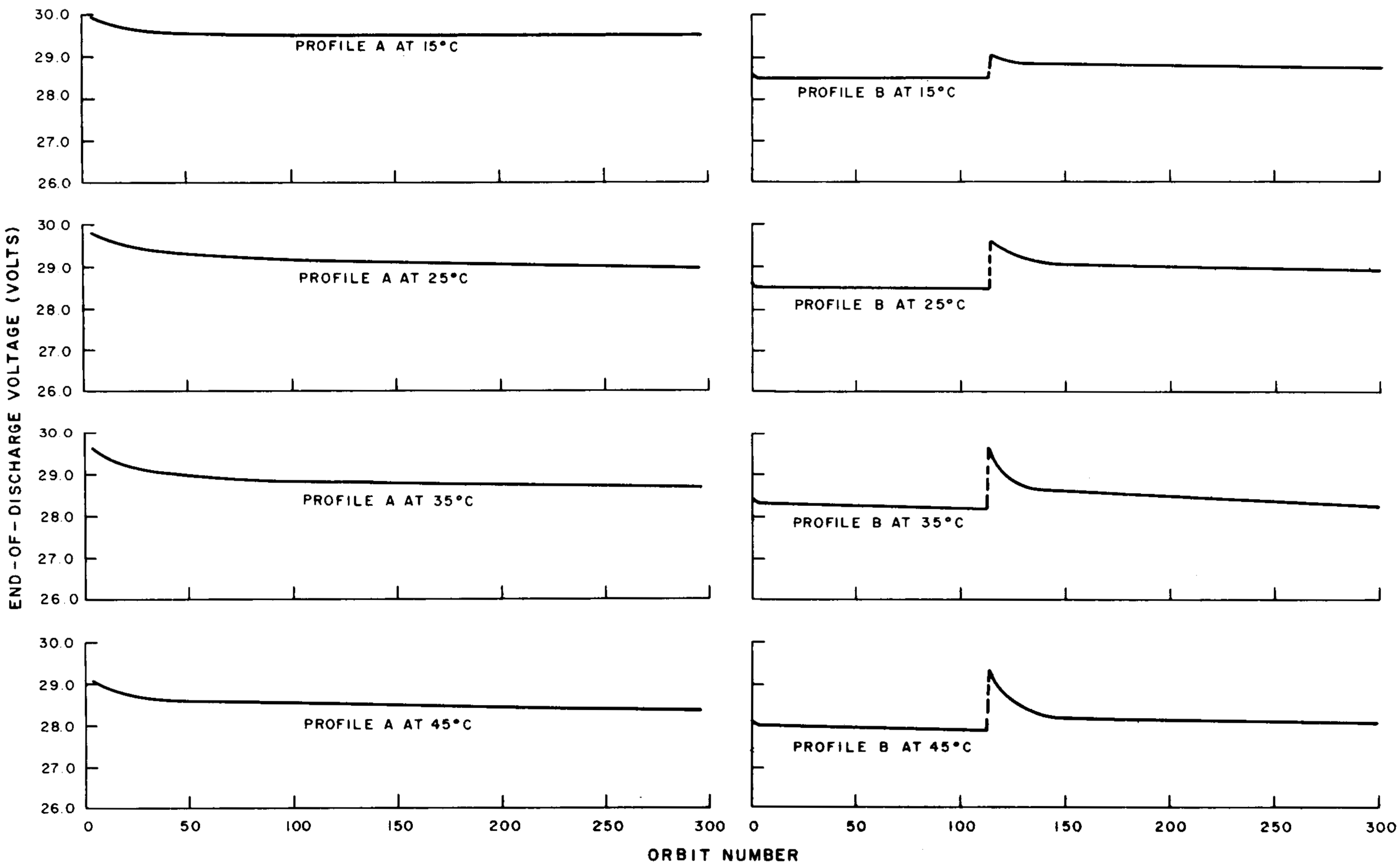


Figure 7. Storage-Cell Cycling Tests, End-of-Discharge Voltage Versus Orbit Number

D. ELECTRICAL TESTING OF PROTOTYPE MODULES

1. General

The two prototype storage modules have been completed. One of these modules, Serial No. 009, contains General Electric storage cells. The other, Serial No. 010, contains Gulton storage cells. Test data obtained during acceptance testing of the cells is summarized in Tables 15 and 16.

2. Electrical Circuit Tests

All of the electrical circuits of the prototype modules were activated and tested by means of the Nimbus-B module tester. The tests were conducted at temperatures of 0, 25, 45 and 55°C. In every case, the electrical performance of the modules met the requirements of Test Procedure TP-CT-1759580 and Performance Specification PS-1759580.

3. Telemetry Calibration

The telemetry outputs of the two prototype storage modules were calibrated. The telemetered parameters are charge current, discharge current, battery voltage, and battery temperature. The calibration curves are shown in Figures 8 through 15.

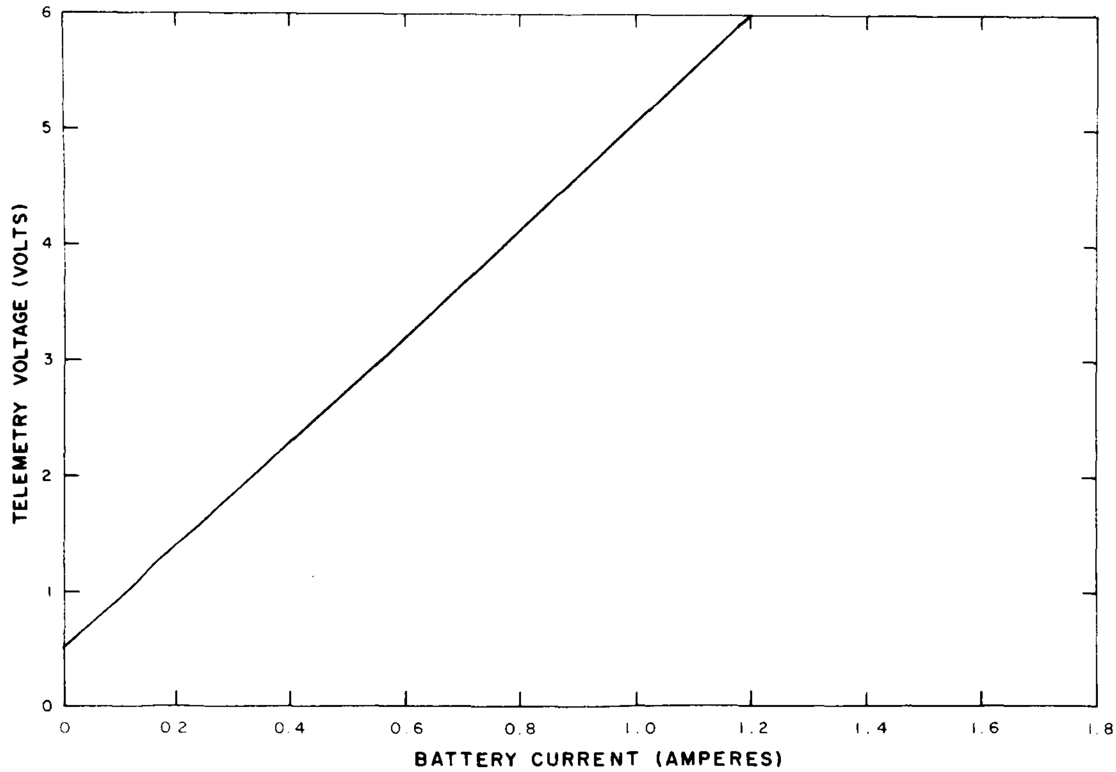


Figure 8. Telemetry Calibration Curve for Battery Charge Current at 25°C, Storage Module Serial No. 009

TABLE 15. SUMMARY OF TEST RESULTS, STORAGE MODULE SERIAL NO. 009 (GENERAL ELECTRIC CELLS)

Module Position No.	Cell Serial No.	Average Capacity at 25° C (minutes)	Maximum Charging Voltage at 25° C (volts)	Cycling Test Maximum Voltage (volts)	Capacity at 50° C (minutes)	Capacity at 0° C (minutes)	Short Test Voltage at 20 Hours (volts)
1	19-42	159	1.437	1.461	74	136	1.229
2	19-43	161	1.455	1.475	78	135	1.221
3	19-47	161	1.453	1.479	80	136	1.217
4	19-48	160	1.444	1.470	75	138	1.230
5	20-6	158	1.452	1.468	78	133	1.228
6	20-10	160	1.437	1.461	80	133	1.226
7	20-11	158	1.450	1.472	82	134	1.229
8	20-12	159	1.434	1.460	84	128	1.219
9	20-13	160	1.431	1.477	84	130	1.223
10	20-21	160	1.438	1.486	88	126	1.225
11	20-23	156	1.448	1.479	83	141	1.241
12	20-25	157	1.448	1.489	84	141	1.237
13	20-26	160	1.437	1.477	89	127	1.219
14	20-27	160	1.438	1.479	85	128	1.224
15	20-29	157	1.457	1.475	81	140	1.239
16	20-32	156	1.449	1.458	79	142	1.236
17	20-35	158	1.453	1.486	82	141	1.238
18	20-36	159	1.449	1.493	85	139	1.241
19	20-37	157	1.452	1.466	81	139	1.238
20	20-38	156	1.455	1.459	82	140	1.230
21	20-42	159	1.444	1.487	83	137	1.224
22	20-45	157	1.454	1.479	82	140	1.236
23	20-49	159	1.434	1.486	88	127	1.225

Note: Capacity test discharges were performed at a 2.0-ampere rate.

TABLE 16. SUMMARY OF TEST RESULTS, STORAGE MODULE SERIAL NO. 010 (GULTON CELLS)

Module Position No.	Cell Serial No.	Average Capacity at 25° C (minutes)	Maximum Charging Voltage at 25° C (volts)	Cycling Test Maximum Voltage (volts)	Capacity at 50° C (minutes)	Capacity at 0° C (minutes)	Short Test Voltage at 20 Hours (volts)
1	434	152	1.448	1.470	87	132	1.226
2	435	154	1.440	1.468	95	132	1.229
3	436	152	1.451	1.462	86	133	1.231
4	437	155	1.442	1.471	93	129	1.224
5	477	160	1.443	1.475	86	133	1.225
6	439	153	1.444	1.466	90	132	1.230
7	442	150	1.440	1.477	88	136	1.239
8	443	152	1.440	1.480	94	125	1.225
9	445	152	1.442	1.472	90	133	1.234
10	447	148	1.457	1.471	84	136	1.243
11	448	148	1.451	1.468	83	137	1.243
12	449	154	1.442	1.470	95	126	1.228
13	451	150	1.451	1.472	84	137	1.241
14	455	152	1.452	1.472	86	131	1.228
15	453	150	1.447	1.466	86	133	1.231
16	460	154	1.446	1.481	90	127	1.223
17	468	162	1.448	1.476	82	134	1.224
18	469	162	1.444	1.479	83	134	1.226
19	440	152	1.446	1.465	88	134	1.231
20	473	159	1.444	1.483	82	140	1.235
21	476	158	1.453	1.474	77	142	1.239
22	478	159	1.463	1.486	77	139	1.238
23	479	162	1.441	1.483	86	134	1.227

Note: Capacity test discharges were performed at a 2.0-ampere rate.

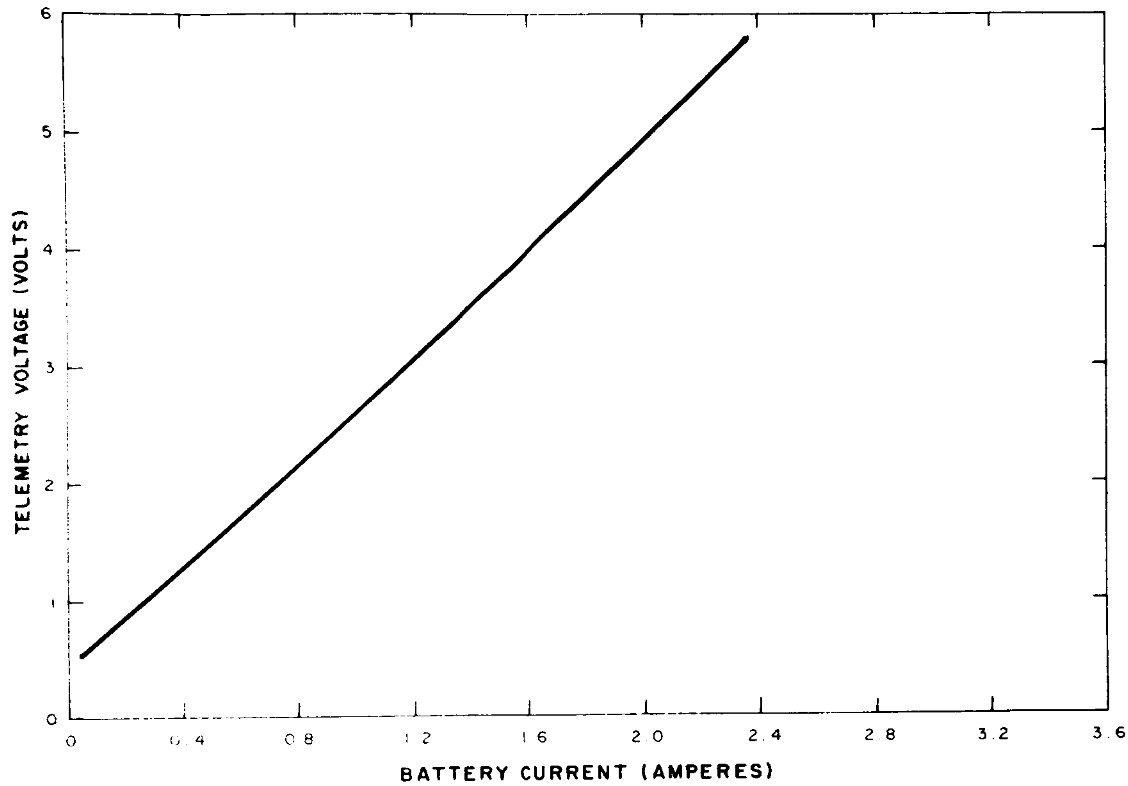


Figure 9. Telemetry Calibration Curve for Battery Discharge Current at 25°C, Storage Module Serial No. 009

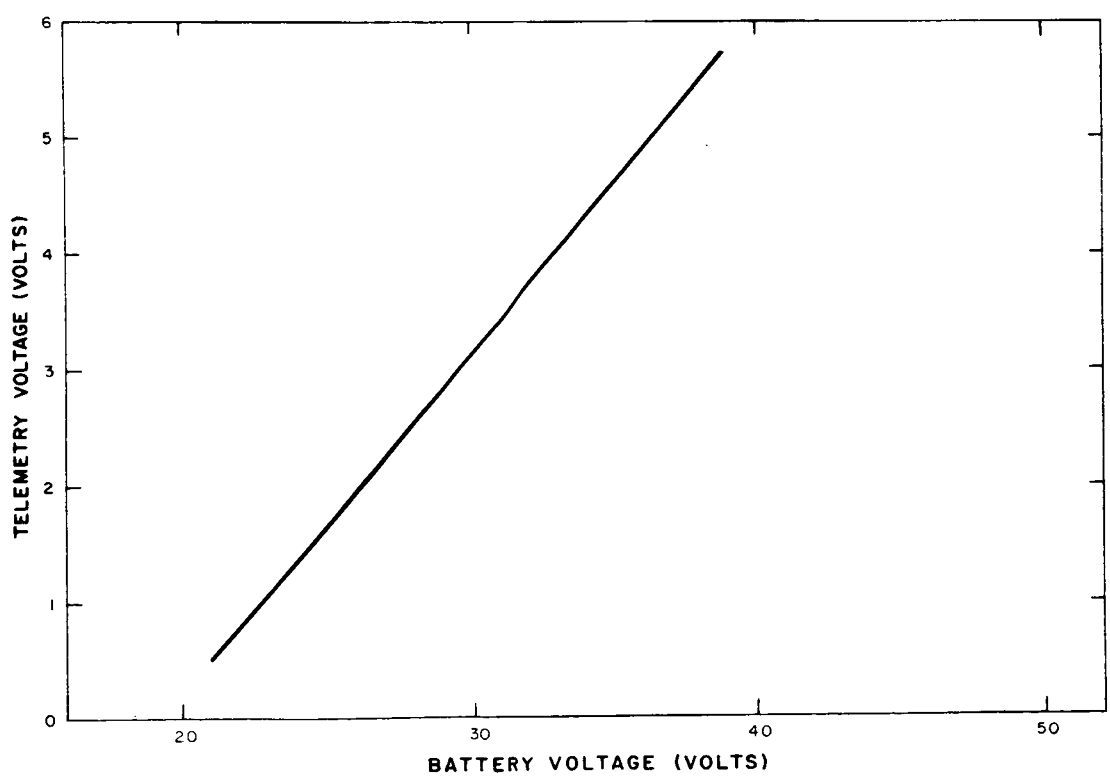


Figure 10. Telemetry Calibration Curve for Battery Voltage, Storage Module Serial No. 009

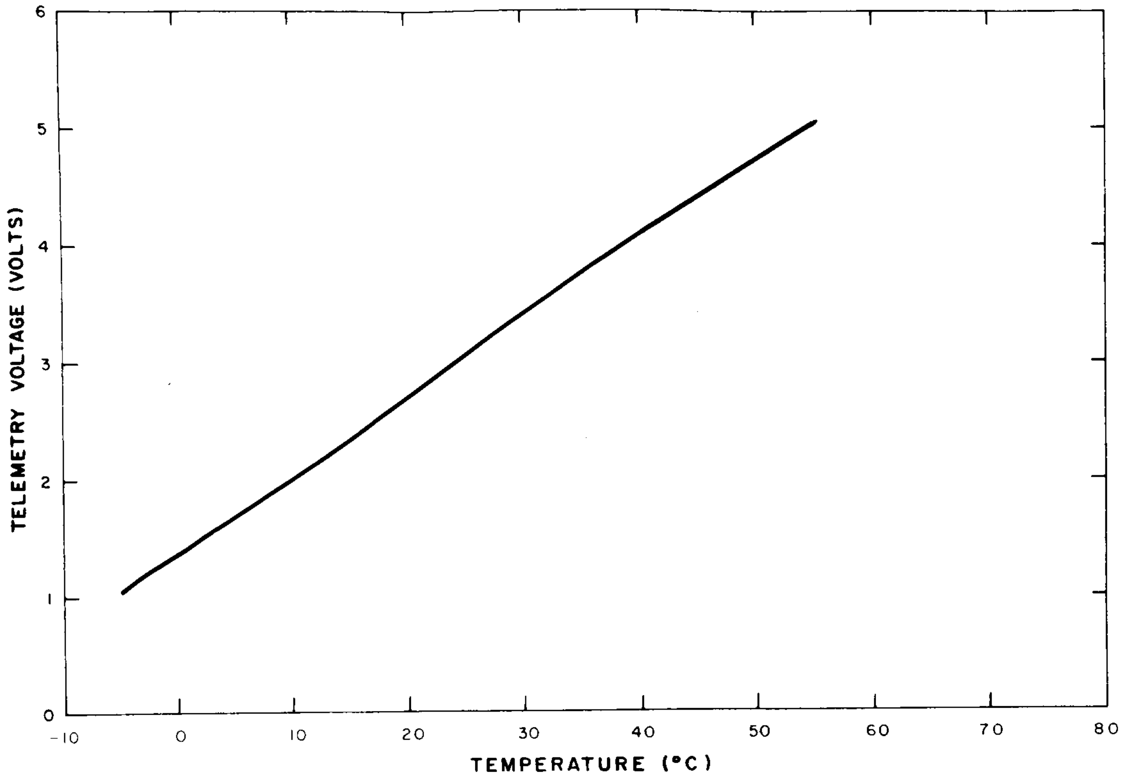


Figure 11. Telemetry Calibration Curve for Battery Temperature, Storage Module Serial No. 009

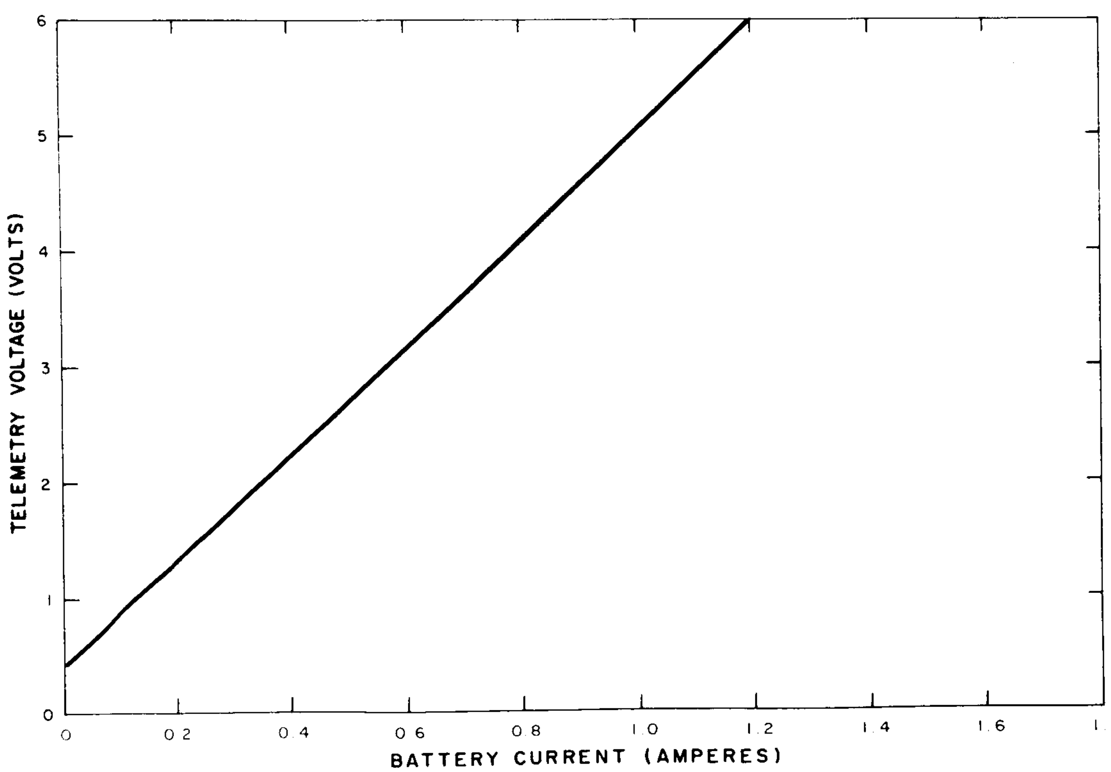


Figure 12. Telemetry Calibration Curve for Battery Charge Current at 25°C, Storage Module Serial No. 010

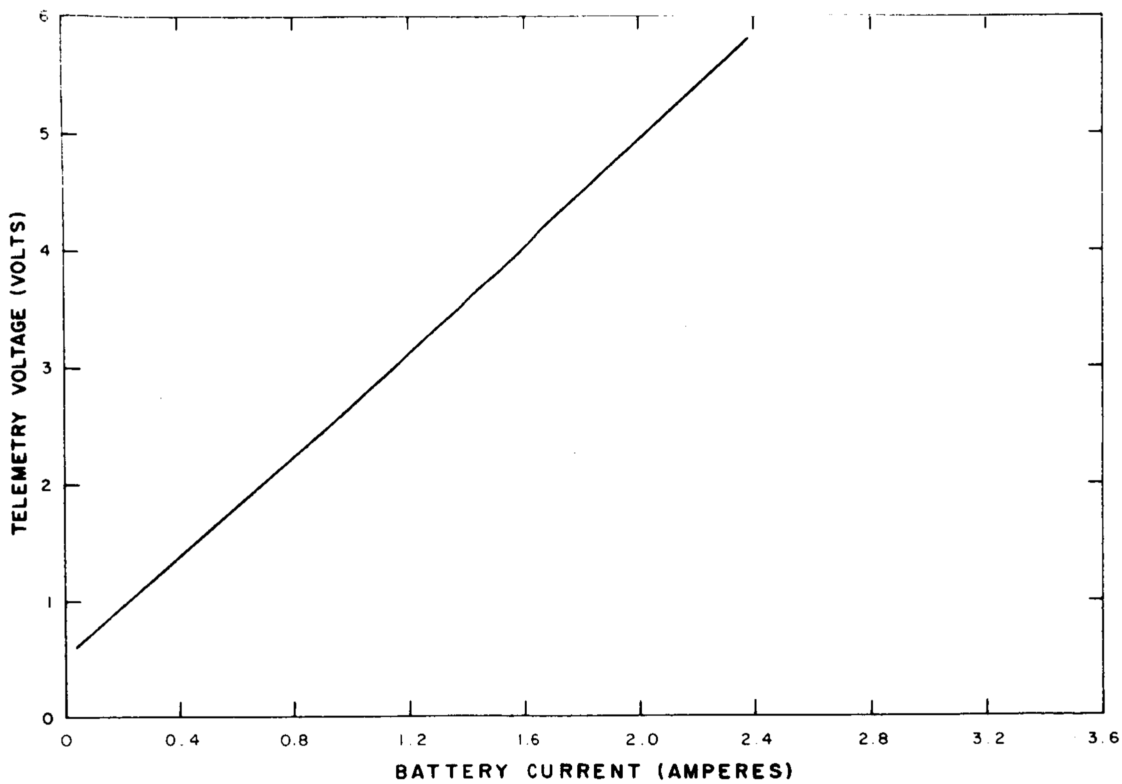


Figure 13. Telemetry Calibration Curve for Battery Discharge Current at 25°C, Storage Module Serial No. 010

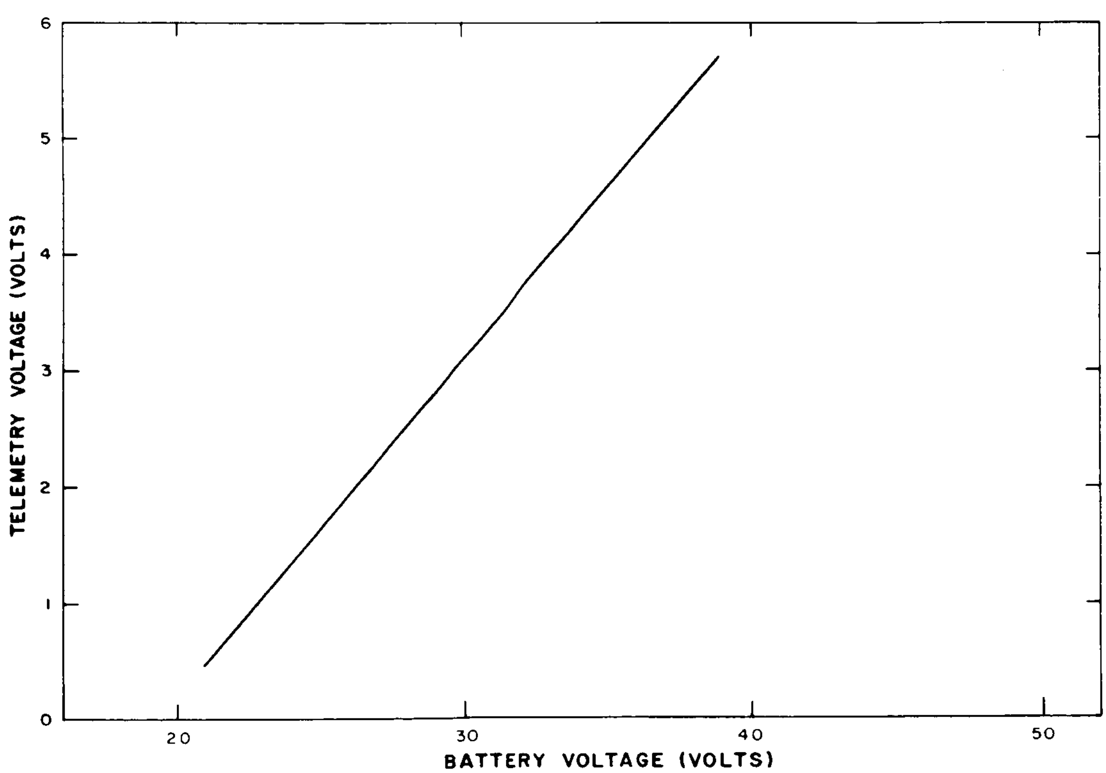


Figure 14. Telemetry Calibration Curve for Battery Voltage, Storage Module Serial No. 010

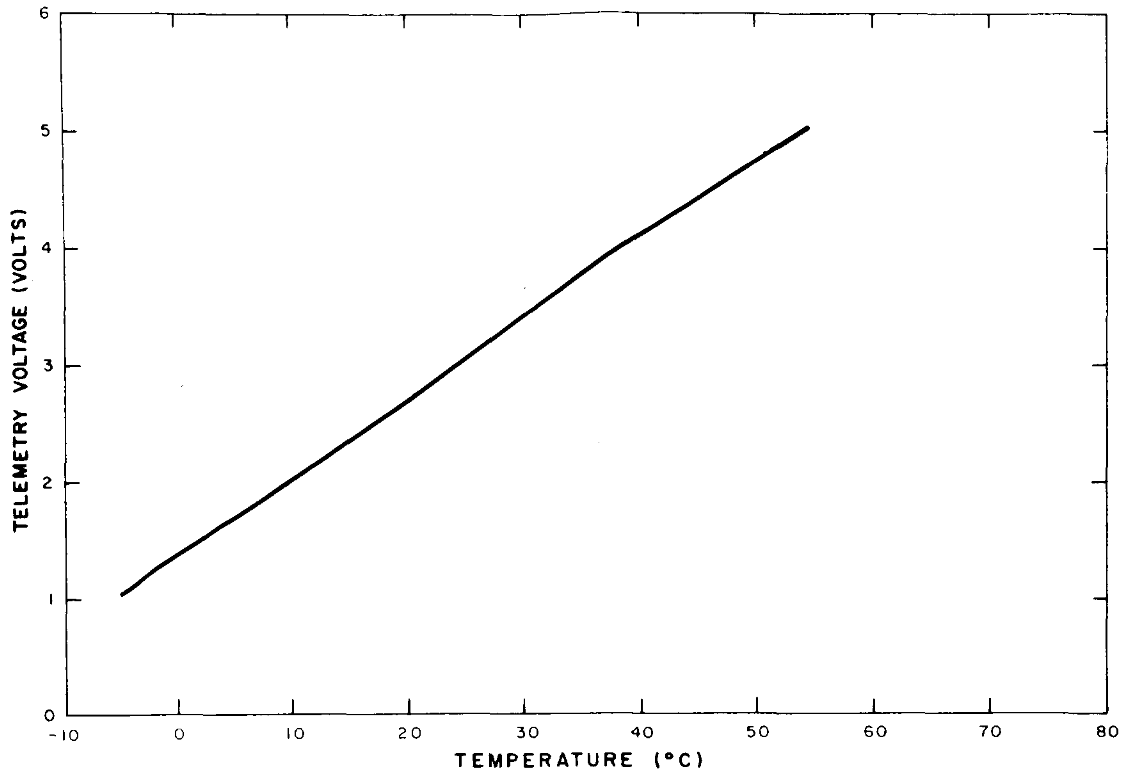


Figure 15. Telemetry Calibration Curve for Battery Temperature, Storage Module Serial No. 010

The curves shown for charge current and discharge current are those obtained at a temperature of 25°C. Representative telemetry voltages for charge current and discharge current at 0, 25, and 45°C are compared in Tables 17 through 20.

TABLE 17. CHARGE-CURRENT TELEMETRY VOLTAGES AT 0, 25, AND 45°C FOR STORAGE MODULE SERIAL NO. 009

Current (amperes)	Charge-Current Telemetry Voltages (volts)		
	@ 0°C	@ 25°C	@ 45°C
1.200	6.036	6.031	6.031
0.800	4.163	4.161	4.149
0.400	2.334	2.323	2.310

4. Capacity Tests

The two modules were subjected to capacity tests. The test consists of: (1) a charge at 0.8 amperes for six hours and 0.4 amperes for four hours, and (2) a discharge at a 1-ampere rate. The test results are given in Table 21.

TABLE 18. DISCHARGE-CURRENT TELEMETRY VOLTAGES AT 0, 25, AND 45°C FOR STORAGE MODULE SERIAL NO. 009

Current (amperes)	Discharge-Current Telemetry Voltages (volts)		
	@ 0°C	@ 25°C	@ 45°C
2.400	5.823	5.795	5.759
1.600	3.995	3.964	3.930
0.800	2.210	2.169	2.137
0.034	0.532	0.505	0.476

TABLE 19. CHARGE-CURRENT TELEMETRY VOLTAGES AT 0, 25, AND 45°C FOR STORAGE MODULE SERIAL NO. 010

Current (amperes)	Charge-Current Telemetry Voltages (volts)		
	@ 0°C	@ 25°C	@ 45°C
1.200	6.044	6.024	6.000
0.800	4.128	4.122	4.089
0.400	2.258	2.236	2.216

TABLE 20. DISCHARGE-CURRENT TELEMETRY VOLTAGES AT 0, 25, AND 45°C FOR STORAGE MODULE SERIAL NO. 010

Current (amperes)	Discharge-Current Telemetry Voltages (volts)		
	@ 0°C	@ 25°C	@ 45°C
2.400	5.850	5.832	5.803
1.600	4.056	4.032	4.001
0.800	2.290	2.263	2.234
0.035	0.650	0.625	0.601

TABLE 21. CAPACITY TEST RESULTS

Test Parameter	Module No. 009	Module No. 010
Battery charge		
Battery voltage at end of charge	32.67 V	32.76 V
Highest cell voltage at end of charge	1.425 V	1.431 V
Lowest cell voltage at end of charge	1.410 V	1.416 V
Battery discharge		
Battery voltage after 3 hours of discharge	28.89 V	28.87 V
Battery voltage at end of discharge	26.99 V	27.18 V
Highest cell voltage at end of discharge	1.198 V	1.211 V
Lowest cell voltage at end of discharge	1.050 V	0.819 V
Discharge time (hours)	5.20	5.19

5. Internal Short Tests

Following the capacity test, both modules were fully let down by placing a one-ohm resistor across each cell until all cell voltages were less than 0.020 volt. The cells were then: (1) open-circuited and allowed to remain in that condition for four hours, (2) charged at 0.500 ampere for five minutes, and (3) open-circuited and left to stand for 20 hours. Battery and cell voltages obtained at the end of the 20-hour period are listed in Table 22.

TABLE 22. INTERNAL SHORT TEST RESULTS

Test Parameter	Module No. 009	Module No. 010
Battery voltage	28.63 V	28.48 V
Highest cell voltage	1.247 V	1.247 V
Lowest cell voltage	1.240 V	1.216 V
Average cell voltage	1.246 V	1.237 V

SECTION IV

SOLAR PLATFORM

A. GENERAL

The tasks performed on the Nimbus-B, Flight-3 solar platforms during the past quarter were authorized under NASA contract NAS5-10158. A description of the work is included in this report, since the platforms will become part of the Nimbus-B power subsystem.

B. TELEMETRY CIRCUITS

During the reporting period, a new platform-temperature telemetry circuit was designed and breadboarded. In addition, the voltage telemetry circuit was modified to provide a voltage-limiting capability. Schematic diagrams of the new circuits are shown in Figures 16 and 17. The output characteristic of the temperature telemetry circuit is shown in Figure 18. Specifications have been written and all parts ordered for incorporating these modifications into the Flight-3 platforms. A list of the electrical parts and their characteristics is given in Table 22.

C. EFFECT OF LONG-TERM STORAGE

A program has been established to determine the effect of long-term storage on the solar platforms, in order to predict their initial output for a launching in 1968. The tasks completed thus far, as part of this program, are as follows:

(1) A procedure was generated for testing the electrical performance of the solar platforms under tungsten illumination. The illuminator used was built for the Lunar Orbiter program and is located at RCA.

(2) The Alternate-4 platform was obtained from General Electric and used to check out the illuminator and the procedures. The Alternate-4 platform was then returned to General Electric.

(3) The thermal properties of the Flight-3 platforms were measured and compared with earlier measurements. No change was apparent in either the absorbtivity or emissivity of the solar cells and back-surface paint (white tilecoat). These results indicate that the temperature profile previously predicted will remain valid.

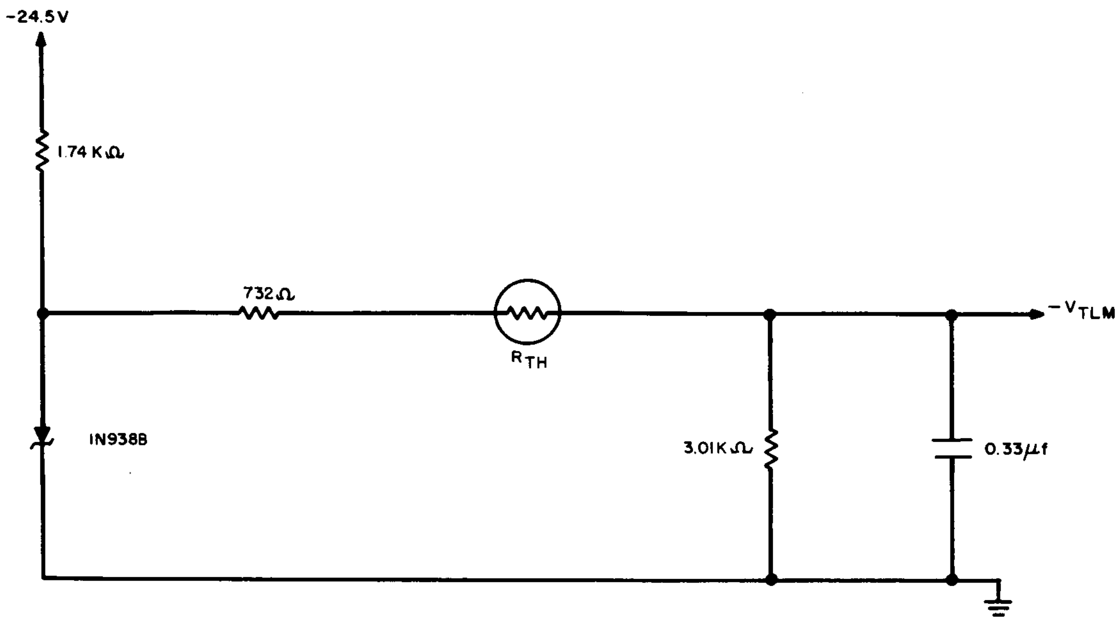


Figure 16. New Platform-Temperature Telemetry Circuit

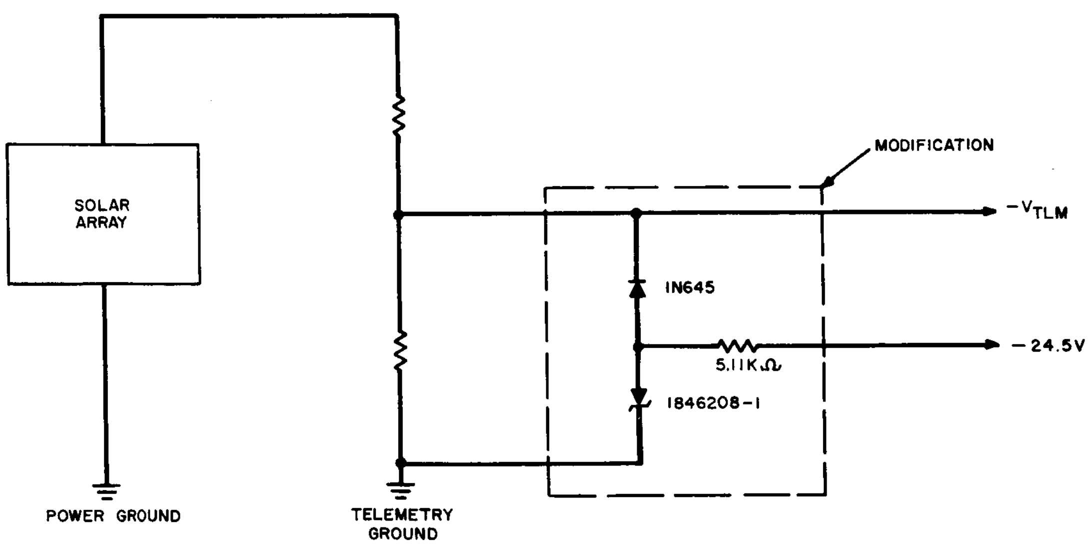


Figure 17. Voltage Telemetry Modification

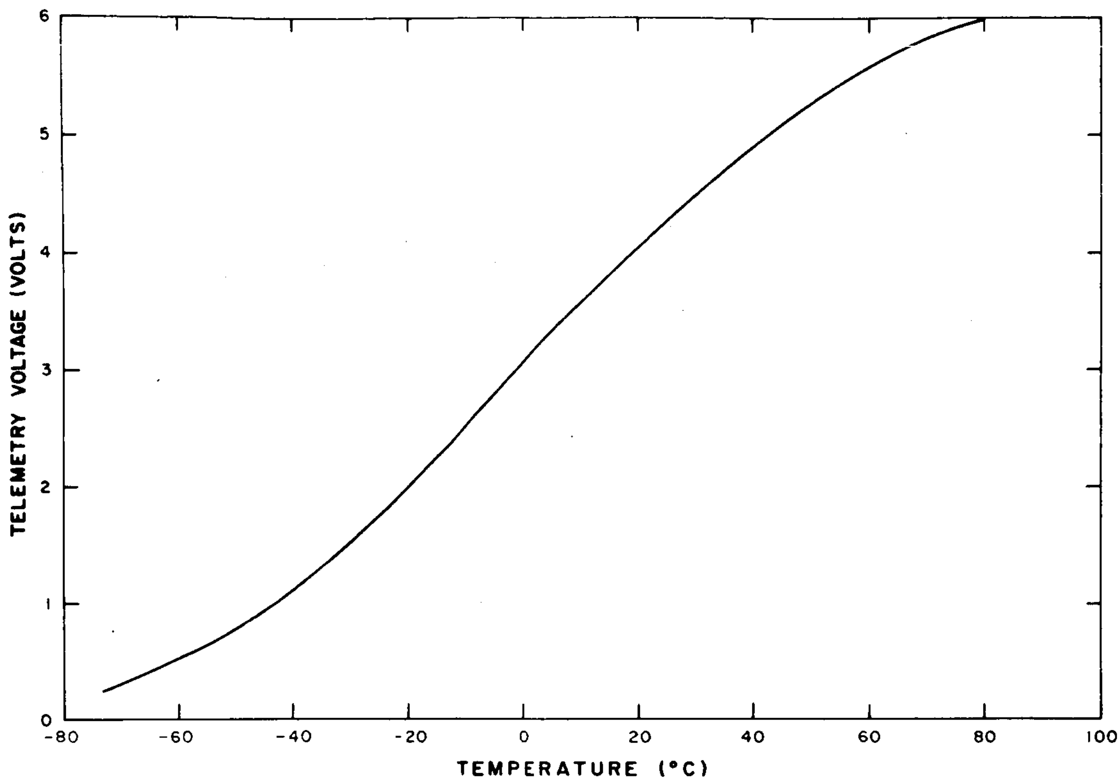


Figure 18. Output Characteristic of Temperature Telemetry Circuit

TABLE 23. CHARACTERISTICS OF NEW TELEMETRY-CIRCUIT PARTS

Part	Value	Type	Power Rating (watts)	Voltage Rating (d-c volts)	Tolerance (%)
Temperature Telemetry Circuit					
Resistor	1.74 kΩ	1729434-6	1.0	—	±1.0
Resistor	732 Ω	1729434-9	1.0	—	±1.0
Resistor	3.01 kΩ	1729434-5	1.0	—	±1.0
Capacitor	0.33 μf	CSR13G334KP		50	±10.0
Zener Diode		1N938B	0.5	9.2535 - 9.3465	±0.5
Thermistor	2.76 kΩ at 25°C	1846693-1			±5.0
Voltage Telemetry Circuit					
Resistor	5.11 kΩ	1729434-8	1.0	—	±1.0
Diode		1N645	0.6	225	
Zener Diode		1846208-1	0.5	8.55 - 9.45	±5.0

SECTION V

GROUND CHECKOUT EQUIPMENT AND TEST DOCUMENTATION

A. GROUND CHECKOUT EQUIPMENT

The engineering drawings for the subsystem tester were completed and released during this quarter. Copies of the instruction manual for the ground checkout equipment have been submitted to GSFC for review.

B. TEST DOCUMENTATION

The following electrical test procedures were begun and will be released during the next quarter:

(1) Procedure for testing the prototype modules connected as a three-module subsystem; and

(2) Procedure for testing the flight model subsystem.

An electrical test procedure for testing the spare flight modules (connected as a four-module subsystem) and the 23 spare storage cells will be prepared and released during the next quarter.

SECTION VI

ENGINEERING RELIABILITY

A. GENERAL STATUS

Engineering Reliability tasks during the past quarter were as follows:

(1) Continuing parts program work on an "as required" basis;

(2) Recommending of parts preconditioning procedure and compilation of preconditioning results; and

(3) Failure analyses.

B. COMPILATION OF PRECONDITIONING DATA

A summary of the parts preconditioning and screening results was completed. The summary covers the entire contract period before January 1, 1967. Both AED and vendor tabulations were reviewed to provide the full scope of high usage parts, which included capacitors, connectors, resistors and semiconductor devices. The summary is presented in Tables 24 through 28.

TABLE 24. PRECONDITIONING RESULTS FOR CAPACITORS

Part Number	Quantity Tested	Total Units Rejected		Preconditioning Site
		No.	%	
1750238	118	0	0	Sprague Electric Company, North Adams, Mass.
1750258	110	0	0	Sprague Electric Company, North Adams, Mass.
1840875	17	0	0	RCA-CSD, Camden, N.J.
CSR13G684KP	139	0	0	Kemet Co., Div. of Union Carbide Corp., Cleveland, Ohio
TOTAL	384	0	0	

TABLE 25. PRECONDITIONING RESULTS FOR CONNECTORS

Part Number	Quantity Tested	Total Units Rejected		Preconditioning Site
		No.	%	
1721489	77	0	0	RCA-AED, Princeton, N.J.
1721490	20	0	0	
1751917	75	0	0	
TOTAL	172	0	0	

C. FAILURE ANALYSIS SUMMARY

Since the beginning of malfunction reporting on the program, ten failure analyses have been performed and corrective action taken. (One of these failure analyses is currently in progress.) No failure has been classified higher than Category 2. Failures in this category will cause mission degradation, but are not catastrophic.

D. FAILURE MODES AND EFFECTS

1. General

The Failure Modes and Effects Analysis performed on the Nimbus-B MOD-3 power subsystem indicated that certain failure modes in the PWM regulator could impose out-of-specification load conditions on parts associated with the part that failed. In order to confirm or negate the findings of the analysis, the indicated failure modes were induced in the breadboard of the PWM regulator, and the effect of the failures was determined. The tests established a significant improvement in the overall Nimbus-B Power Supply Reliability Estimate.

2. Performance of the PWM Regulator under Induced Failure Modes

a. GENERAL

The induced failure modes and test data are described in the following paragraphs. Three 12-volt lead-acid batteries connected in series were used to simulate the storage modules. Power supply wire sizes and lengths were approximated to represent the actual flight hardware. All component designations correspond to those in RCA Drawing 1849871.

TABLE 26. PRECONDITIONING RESULTS FOR DIODES

Part No.	Quantity Tested	Total Units Rejected		Initial				Final				Preconditioning Site
				BV		I_{CBO}		BV		I_{CBO}		
		No.	%	No.	%	No.	%	No.	%	No.	%	
JAN1N457	50	1	2.0							1	2.0	RCA-AED, Princeton, N.J.
JAN1N645	643	32	4.97			2	0.31			30	4.66	
JAN1N3189	38	3	7.89			3	7.89					
USN1N755	1											
USN1N758A	30											
USN1N935B	13											
USN1N938B	69	2	2.9	1	1.45					1	1.45	
USN1N944B	42	1	2.38					1	2.38			
USN1N3026B	13											
USN1N3600	279	5	1.79							5	1.79	
1N751A	10											
1N756	6	1	16.66					1	16.66			
1N764	10	1	10.0	1	10.0							
1N816	30	6	20.0	1	3.44					5	16.66	
1N821	5	1	20.0	1	20.0							
1N938	10											
1N992B	26	14	53.84	1	3.84			8	30.76	5	19.4	
1840124	30	7	23.33							7	23.33	
1840996	6											
1840998	17											Westinghouse Electric Corp.,
1840999	23											Philadelphia, Pa.
1846201	42	1	2.38							1	2.38	RCA-CSD, Camden, N.J.
1846206	92											Dickson Electronics, Oaklyn, N.J.
1846207	51	6	11.76							6	11.76	RCA-AED, Princeton, N.J.
1846208	48	11	22.91							11	22.91	Dickson Electronics, Oaklyn, N.J.
TOTAL	1568	92	5.86	5	0.32	5	0.32	10	0.63	72	4.59	

TABLE 27. PRECONDITIONG RESULTS FOR RESISTORS

Part No.	Quantity Tested	Total Units Rejected		Units Rejected Due to Change		Failure During Screening		Initial and Final Parameter Rejection		Preconditioning Site
		No.	%	No.	%	No.	%	No.	%	
RB54CE	12									Dale Electronics, Inc., Columbus, Neb.
RB56CE	30									RCA-AED, Princeton, N.J.
RC07GF	388	6	1.54	6	1.54					
RC20GF	92	3	3.26					3	3.26	
RC32GF	50									
RC42GF	20									
RN55C	20									
RN60C	198	5	2.52					5	2.52	
RN60C	20									Ward Leonard Electric Co., Hagerstown, Md.
RN75C	24	6	25.0			6	25.0			RCA-AED, Princeton, N.J.
RW69V	32	4	12.5					4	12.5	RCA-AED, Princeton, N.J.
1840914	32									Sage Electronics Corp., Rochester, N.Y.
1840929	59	3	5.08					3	5.08	RCA-AED, Princeton, N.J.
1846209	283	1	0.35					1	0.35	Shallcross Mfg. Co., Selma, N.C.
TOTAL	1260	28	2.22	6	0.48	6	0.48	16	1.26	

TABLE 28. PRECONDITIONING RESULTS FOR TRANSISTORS

Part No.	Quantity Tested	Total Units Rejected		Initial				Final				Preconditioning Site
				H_{FE}		I_{CBO}		H_{FE}		I_{CBO}		
		No.	%	No.	%	No.	%	No.	%	No.	%	
JAN2N1358	39	1	2.56							1	2.56	RCA-CSD, Camden, N.J.
USA2N930	15	5	33.3							5	33.3	RCA-AED, Princeton, N.J.
* USA2N2016	20	2	10.0									RCA-CSD, Camden, N.J.
2N722	42	2	4.76							2	4.76	RCA-AED, Princeton, N.J.
2N916	16	9	56.25			1	6.25	8	50.0			
2N956	27	14	51.85	2	7.40			12	44.4			
2N2210	70	1	1.43					1	1.43			Motorola, Phoenix, Arizona
CTM105VAJ	15											RCA-AED, Princeton, N.J.
CTM124VAJ	14											
CTM153VAJ	10											
CTM394VAJ	6											
CTM684VAJ	10											
CTM822VAJ	14											
CTM332VBJ	14											
CTM472VBJ	6											
CTM563VBJ	14											
1846612	60											
TOTAL	392	34	8.67	2	0.51	1	0.255	21	5.35	8	2.04	

* X-ray is only requirement for preconditioning of USA2N2016.

b. SIMULATED SHORT OF TRANSISTORS Q1 AND Q20

It was proposed that a Q1 and then a Q20 collector-to-emitter short be simulated by connecting a high-current relay or switch to the collectors and emitters. This switch would be closed when operating under worst-case conditions (high-voltage input and high-current load). Since inhibit signals are not effective in reducing the relay contact load under this condition, this test would determine if any significant damage is done to the K1-K2 relay by interrupting its contact load current.

Design Engineering and Engineering Reliability agreed that it was not necessary to perform this test. The regulator had been subjected repeatedly to this type of condition without any significant damage to the relay.

c. SIMULATED SHORT OF DIODE CR27 OR CR28

It was assumed that CR27 or CR28, a 1N3910 diode, shorted while the power subsystem was in operation. To simulate the short, a high current relay or equivalent switch was to be used to connect an external 1N3910 diode in a forward direction across the CR27-CR28 reverse-biased diodes presently in the circuit. The external diode was expected to fail by shorting and then to open internally.

The 1N3910 diode is rated at 35 amperes and requires a large amount of current to destroy its junction. Therefore, before connecting the diode in a forward direction in the regulator and possibly destroying the output chokes (L3 & L2), a test was performed to determine the current required to short and clear the diode. The test setup is shown in Figure 19.

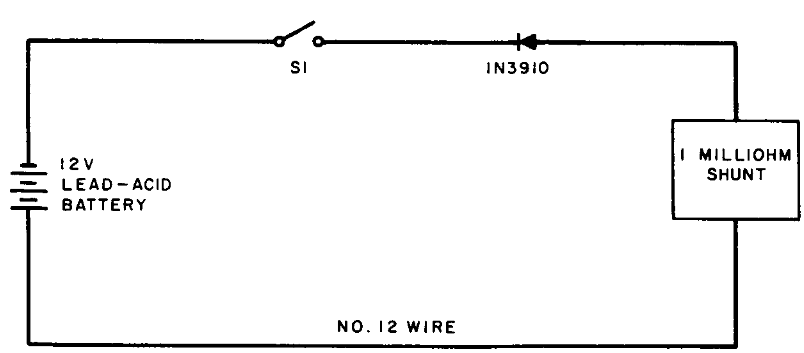


Figure 19. Test Setup for Determining the Current Required to Short and Clear the Diode

Switch S1 was closed and battery current across the 1-milliohm shunt was monitored. The current started at 550 amperes and steadily decreased to 200 amperes after 14 seconds, as shown in Figure 20. At t = 14 seconds, the No. 12 wire melted, breaking the current path. The diode was checked and found satisfactory.

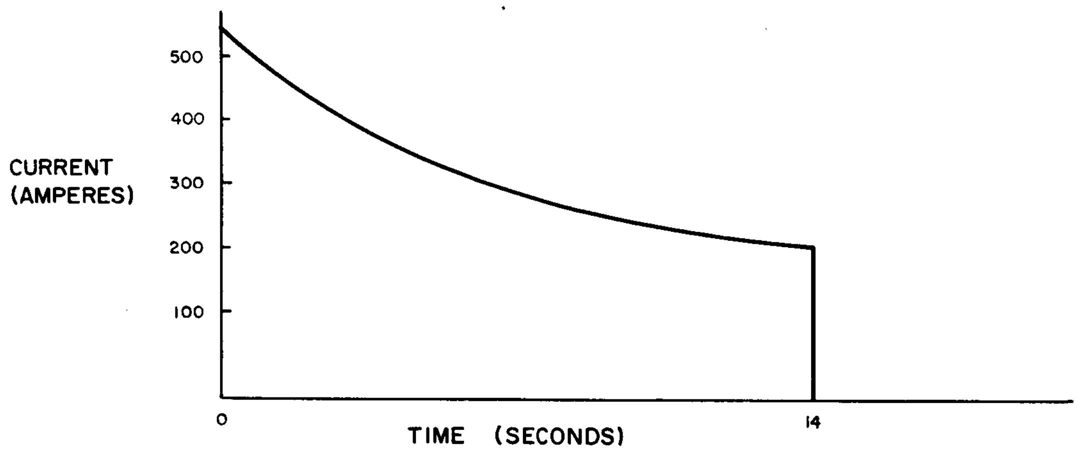


Figure 20. Short-Circuit Current versus Time

It was obvious from the above test that blowing the diode in the regulator as called for would have destroyed the output choke. However, the following conclusions can be reached from the above data.

(1) Should the Nimbus-B battery tap be capable of delivering 500 amperes, it is probable that the No. 12 wiring and output chokes will be destroyed before the diode clears.

(2) The 1N3910 diode normally conducts an average current of approximately 5 amperes. It is extremely improbable that this amount of stress would cause a short, since 550 amperes melted the wire before the diode would short.

d. SIMULATED SHORT OF CAPACITOR C17, C18, OR C19

The unregulated-bus input filter was assumed to have one of its capacitive elements (C17, C18, or C19) shorted to ground. It was desired to make the following determinations under this condition:

(1) Measure the unregulated-bus input current during this test;

(2) Determine the time taken for the short to clear;

(3) Determine if the short-circuit currents have damaged the 0.5-millihenry choke winding L2; and

(4) Determine the possible damage sustained by the storage module disconnect diodes if the capacitor short-circuit current measures more than 50 amperes for 1 second.

The test setup that was used is shown in Figure 21. To simulate the shorted condition, a 100-ampere mercury relay was used to connect a capacitor (29F3077, rated at 350 microfarads and 75 volts at 125° C) in a reversed direction across the input filter section consisting of C17, C18 and C19. A timing diagram showing the sequence of events beginning at the closing of the relay contacts is shown in Figure 22. The diagram shows that the capacitor cleared in 9.4 seconds. The maximum current (45 amperes) was not damaging to any of the eight 2N1358 diode junctions or the input choke L2. The operation of the regulator was not affected during this induced failure.

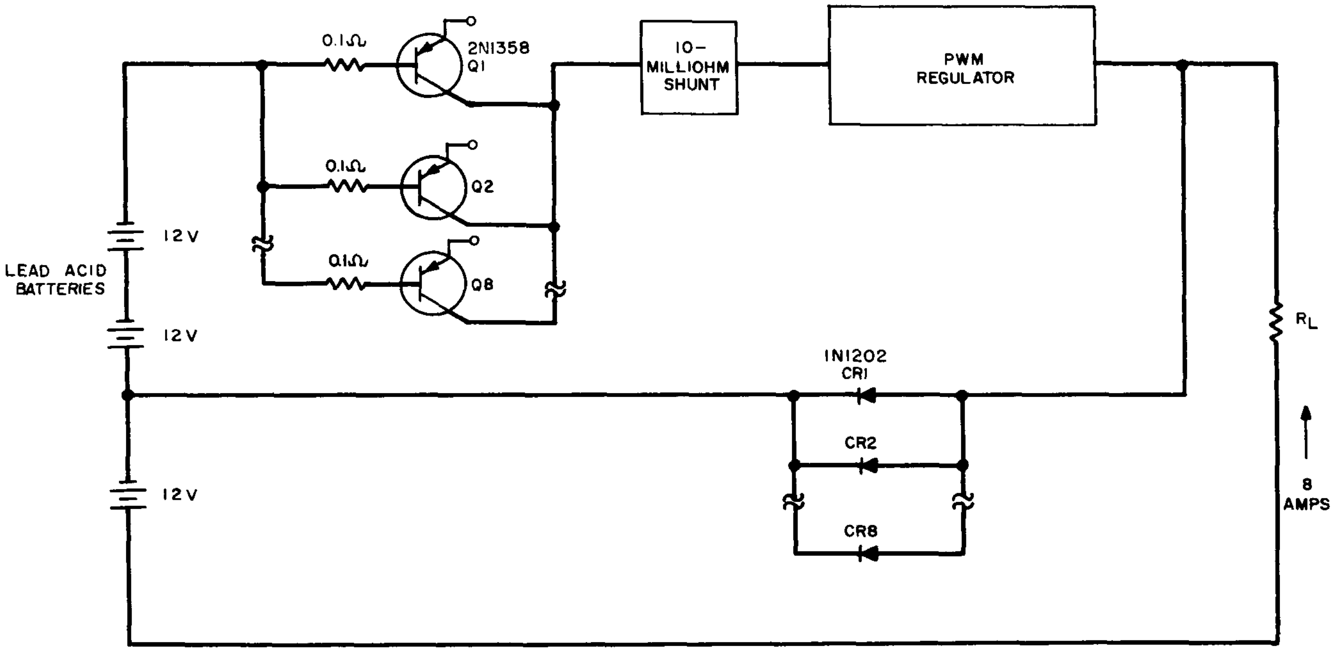


Figure 21. Test Setup for Simulated Short of Capacitor C17, C18, or C19

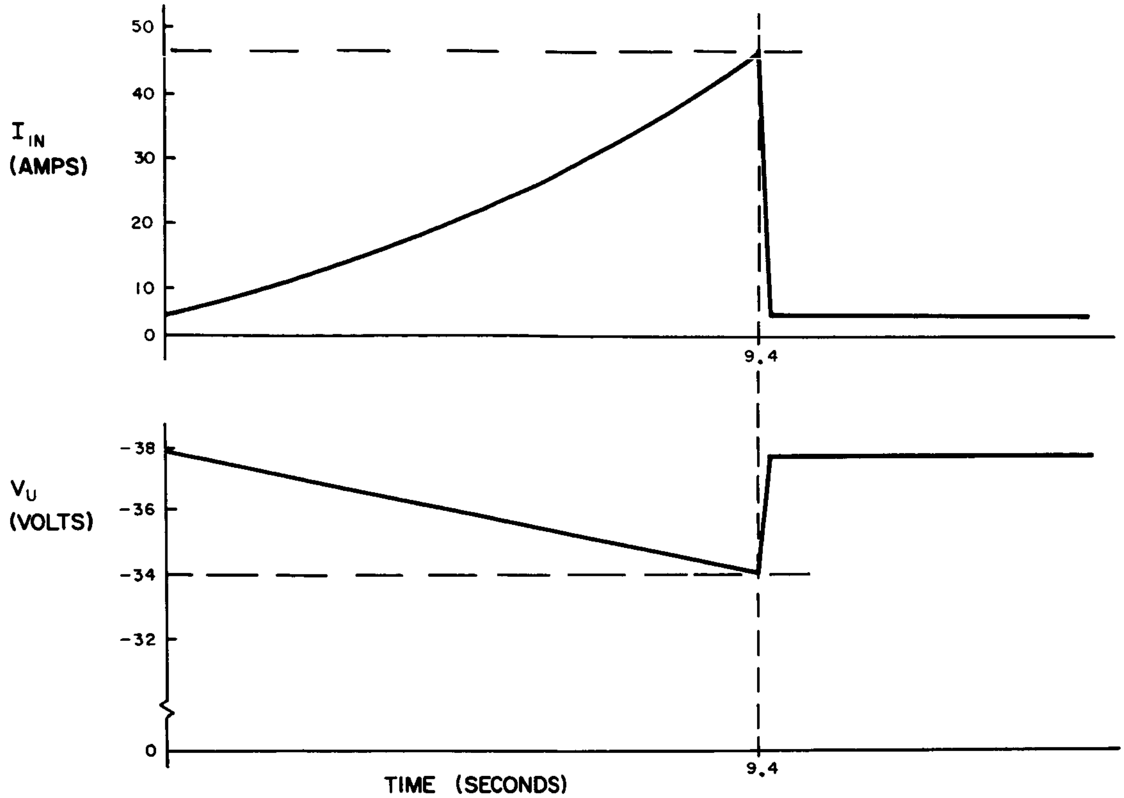


Figure 22. Timing Diagram, Simulated Short of Capacitor C17, C18, or C19

e. SIMULATED SHORT OF DIODE CR29

It was assumed that CR29, a 1N4824 diode, shorted and then cleared while the power subsystem was in operation. Since this diode is non-redundant, it was important to determine the effect of a diode open-circuit. An evaluation of the resulting transients at the collector of Q1 was also desired.

The test setup used was the same as that shown in Figure 21 for simulated short of capacitor C17, C18 or C19. Input current, battery tap current, regulated bus voltage, and unregulated bus voltage were the monitored parameters. These parameters and their variations during the induced failure are shown in Figure 23. As shown in the figure, the diode blow time was 130 milliseconds, and the regulator recovery time was 380 milliseconds. The input current peaked at 120 amperes at the inception of the diode connection, and the battery tap supplied 150 amperes for 130 milliseconds to short and clear the diode. Regulator efficiency was not affected by the opening of the diode. Normally, the diode is not operating; it is only placed in operation if the R113-C21 network fails.

The anomaly in the regulated bus waveform at 500 milliseconds (Figure 23) is caused by the regulator attempting to return to the current limit mode. This phenomenon has been explained in detail in a letter (NB-SP-PO-070) dated July 28, 1966.

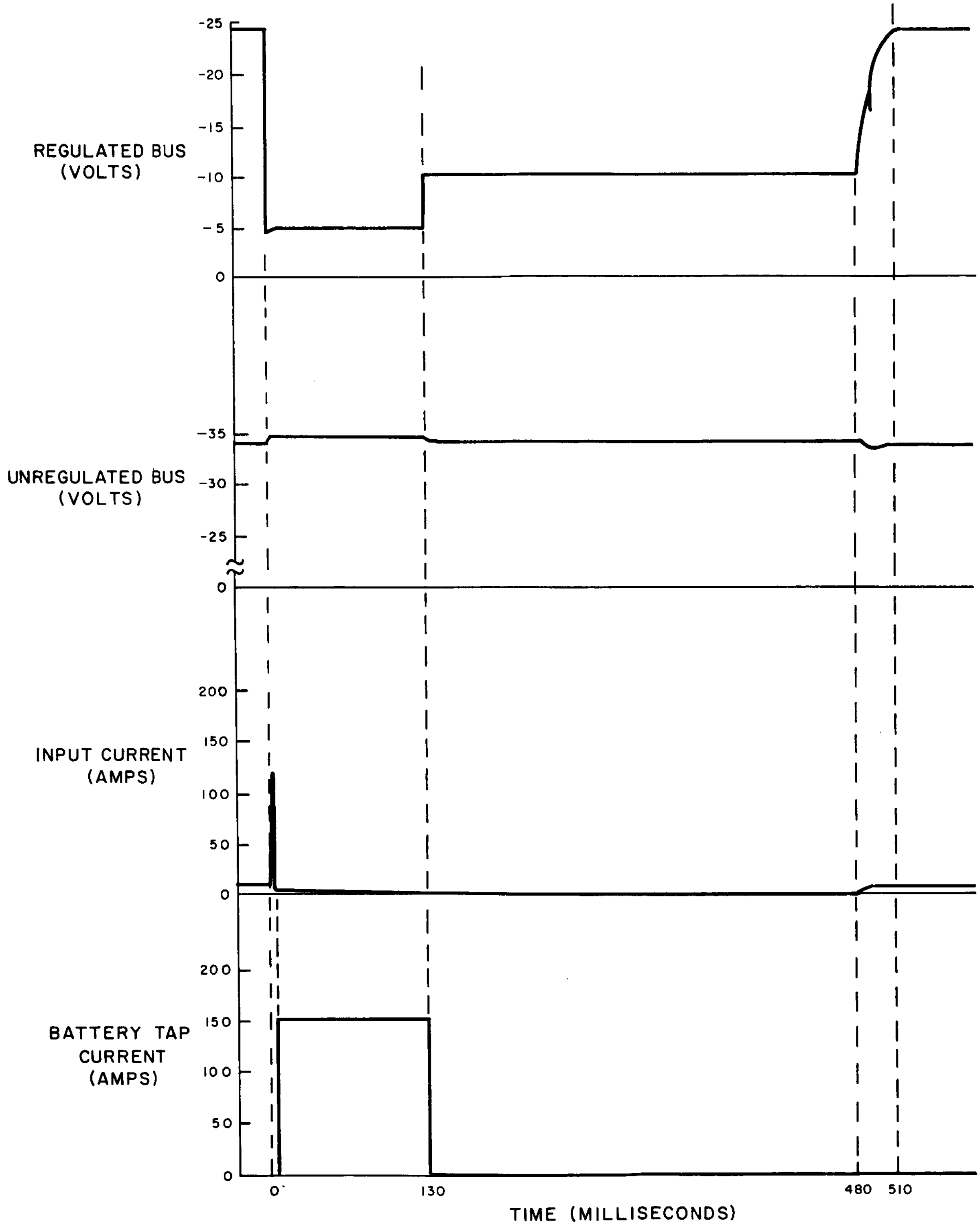


Figure 23. Timing Diagram, Simulated Short of Diode CR29

f. SIMULATED SHORT OF INDUCTOR L2 OR L3

(1) Short-Circuit of Inductor L2

A short circuit of inductor L2 was simulated by connecting a heavy jumper across its terminals. This short reduced the efficiency of the PWM regulator because it changed the collector-emitter saturation voltage of transistor Q1. The inclusion of L2 provides complete saturation of Q1 and improves regulator efficiency. This improvement occurs because power that would be dissipated in Q1 without L2 is stored in L2 during the "ON" time of Q1 and is delivered to the load during the "OFF" time of Q1. Typical efficiency reductions due to the shorting of L2 are shown in Table 29.

TABLE 29. EFFICIENCY REDUCTION DUE TO SHORT-CIRCUITING OF L2

L2 Operative			L2 Short-Circuited		
V_u	I_o	Efficiency	V_u	I_o	Efficiency
-30	5	86.8%	-30	5	86.1%
-30	8	89.5%	-30	8	88.2%
-30	10	90.8%	-30	10	89.8%

The shorting of L2 reduces the efficiency of the regulator, but does not result in any other detrimental effect.

(2) Short-Circuit of Inductor L3

Inductor L3 and the regulator output capacitors form an energy storage network. Therefore, short-circuiting of L3 will reduce regulator efficiency and increase regulator output ripple. A comparison of efficiencies with L3 operative and short-circuited are given in Table 30. The output ripple voltage with and without L3 is shown in Figure 24.

It was also noted that current-limiting operation of the regulator began at a load current of 17 amperes with L3 short-circuited. Current-limiting operation with L3 operative is set to begin at a load current of 21 amperes. The shift in the operating point is due to larger peak current caused by the short-circuiting of L3.

TABLE 30. EFFICIENCY REDUCTION DUE TO SHORT-CIRCUITING OF L3

L3 Operative			L3 Short-Circuited		
V_u	I_L	Efficiency	V_u	I_L	Efficiency
-30	5	86.8%	-30	5	80.9%
-30	8	89.5%	-30	8	83.8%
-30	10	90.8%	-30	10	86.0%

In summary, short-circuiting of L3 affects regulator operation as follows:

(1) Reduced efficiency;

(2) Increased output voltage ripple; and

(3) Earlier current-limiting operation.

g. SIMULATED SHORT OF TRANSISTORS Q4 AND Q5

The effect of a collector-emitter short in both transistor Q4 and Q5 was considered. Should this type of short occur, the K1 or K2 relay coil that is next to be energized is energized in only one coil section, because no inhibit signal is present. As a result, both PWM regulators will operate in parallel, and the oscillators of both regulators will be in synchronism.

Design Engineering and Engineering Reliability agreed that, from the standpoint of failure modes and effects, a test of this condition was not necessary, because it can only be created by a double failure.

h. SIMULATED SHORT OF CAPACITOR C22, C23, C24 OR C25

The capacitor bank consisting of C22, C23, C24 and C25 was assumed to develop a shorted element while the power subsystem was in operation. It was desired to make the following determinations under this condition:

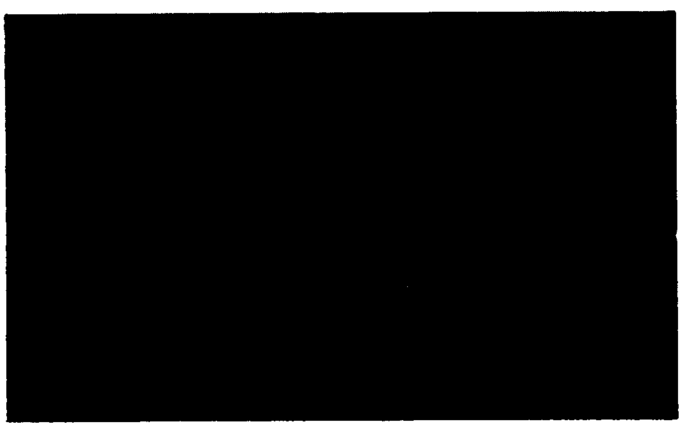
(1) Measure the unregulated-bus input current during the test;

(2) Determine the time required for the short to clear; and

(3) Measure the current required in the 15th cell disconnect diodes to clear the short.

VERTICAL: 100 MV/CM
HORIZONTAL: 50 MSEC/CM

(a) L3 IN CIRCUIT



VERTICAL: 100 MV/CM
HORIZONTAL: 50 MSEC/CM

(b) L3 SHORT-CIRCUITED

Figure 24. Regulator Output Ripple With and Without Inductor L3

The test setup shown in Figure 21 was used to perform this test. A capacitor (CL54CL121UN3, rated at 120 microfarads and 75 watts at 125°C) was short-circuited by driving a screw through its case to the foil. This method of creating a shorted capacitor was selected because it is difficult to cause a short in a reversed capacitor of this type with the current available from a 24-volt source.

To determine if the battery-tap current was capable of clearing the short, the shorted capacitor was connected across the capacitor bank by means of a high-current mercury relay. A timing diagram for the series of events beginning at the closing of the relay is shown in Figure 25. The shorted capacitor was cleared in 960 milliseconds.

3. Conclusions

A significant reduction occurred in the category 1 (catastrophic) failure rates because postulated failures were negated by the positive self-protection built into the regulator. The items indicated by an asterisk in Table 31 have changed from category 1 (catastrophic failures) to category 3 (minor failures).

The new failure rate for category 1 is 1.1123%/1000 hours, or 12.9 percent of the total parts count failure rate. Before the start of the failure mode testing program, the failure rate for category 1 was 1.2300%/1000 hours, or 14.1 percent of the total parts count failure rate.

The total failure rate for category 2 remains the same (0.9443%/1000 hours).

The failure rate for category 3 has increased from 6.5626%/1000 hours to 6.6803%/1000 hours, or from 75.1 percent to 76.9 percent of the total parts count failure rate.

In summary, the failure rate for category 1 (exclusive of the connectors) has been reduced by 44 percent due to the results of the induced failure-mode testing program. The category 1 failure rate for the connectors represents a worst-case condition.

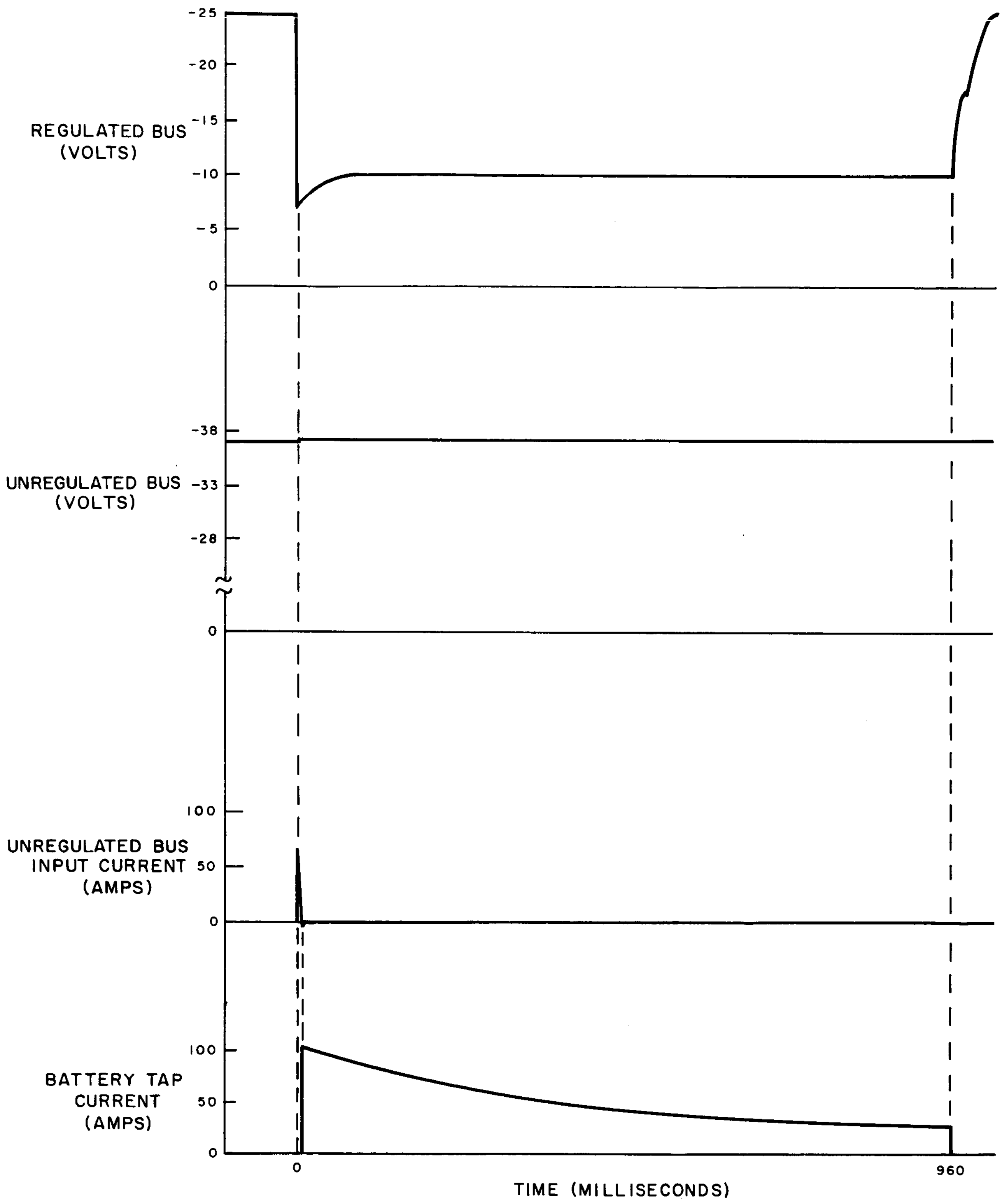


Figure 25. Timing Diagram, Simulated Short of Capacitor C22, C23, C24, or C25

TABLE 31. FAILURE MODES AND EFFECTS TEST RESULTS

Failure	Failure Rates (%/1000 hours)		
	Before Testing	After Testing	
	Category 1	Category 1	Category 3
Switchover Relay*	0.0324	—	0.0324
RBC Driver	0.0154	0.0154	—
K1-K2 Failure*	0.0002	—	0.0002
False Switching	0.0200	0.0200	—
Open Inductor in Energy Storage Network	0.1127	0.1127	—
Shorted Inductor in Energy Storage Network*	0.0644	—	0.0644
Shorted Diode in Energy Storage Network	0.0032	0.0032	—
Unregulated Filter Capacitor Shorted*	0.0075	—	0.0075
Shorted Capacitor in Energy Storage Network*	0.0100	—	0.0100
Shorted Damping Diode in Energy Storage Network*	0.0032	—	0.0032
Connectors	0.9610	0.9610	—
TOTALS	1.2300	1.1123	0.1177

SECTION VII

PROGRAM FOR NEXT REPORTING PERIOD

A. GENERAL

This section enumerates the tasks scheduled for completion during the next quarter.

B. POWER SUBSYSTEM

At the power subsystem level, RCA plans to:

(1) Complete the system test procedures and the instruction manuals for the power subsystem and ground checkout equipment;

(2) Complete all testing of the prototype and flight spare modules, and perform an evaluation of the test results; and

(3) Begin thermal-vacuum cycling of the flight subsystem.

C. CONTROL MODULE

Control-module work planned for the next quarter is as follows:

(1) Final assembly of the second flight model; and

(2) Electrical performance testing and final potting of the two flight modules.

D. STORAGE MODULE

Storage-module work planned for the next quarter is as follows:

(1) Electrical performance testing and final potting of the first three flight modules, which were completed in February; and

(2) Final assembly and electrical performance testing of the eight flight modules remaining.

E. ENGINEERING RELIABILITY

Engineering-reliability tasks planned for the next quarter are:

(1) Continuing parts program effort on an "as required" basis for new parts needed as a result of design changes;

(2) Compilation of remaining preconditioning results; and

(3) Failure analyses.